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TECHNICAL REPORT

Medical Effects and Dosimetric Data from Nuclear Tests at the Semipalatinsk Test Site

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14. ABSTRACT (Maximum 200 words)

In the former Soviet Union, two sites were used for most surface or atmospheric nuclear tests. One of these was at Novaya Zemlya in the arctic, but the earlier and more used of the two was in what is now the Republic of Kazakhstan. The Semipalatinsk Test Site (STS), or Polygon as it was called, was instituted in 1947.

Data relating to the radiation levels were declassified in 1992 and are published in the first two tables of this report. Basically, the population was exposed to three sources of radiation: acute external gamma irradiation as the plume from the explosion passed over the areas; external gamma (and probably beta) irradiation from the fallout as it settled on the ground and the people themselves; and internal gamma, beta, and small amounts of alpha irradiation. Medical examinations conducted under this report and compared with data from previous expeditions have shown a significant disparity in health status between inhabitants of villages in the immediate neighborhood of the STS and inhabitants of similar settlements remote from the STS.

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CONVERSION TABLE

Conversion Factors for U.S. Customary to metric (SI) units of measurement.

MULTIPLY ⟶ BY ⟶ TO GET
TO GET ⟵ BY ⟵ DIVIDE

angstrom	1.000 000 x E -10	meters (m)
atmosphere (normal)	1.013 25 x E +2	kilo pascal (kPa)
bar	1.000 000 x E +2	kilo pascal (kPa)
barn	1.000 000 x E -28	meter^2 (m^2)
British thermal unit (thermochemical)	1.054 350 x E +3	joule (J)
calorie (thermochemical)	4.184 000	joule (J)
cal (thermochemical/cm^2)	4.184 000 x E -2	mega joule/m^2 (MJ/m^2)
curie	3.700 000 x E +1	*giga bacquerel (GBq)
degree (angle)	1.745 329 x E -2	radian (rad)
degree Fahrenheit	$t_k = (t^\circ f + 459.67)/1.8$	degree kelvin (K)
electron volt	1.602 19 x E -19	joule (J)
erg	1.000 000 x E -7	joule (J)
erg/second	1.000 000 x E -7	watt (W)
foot	3.048 000 x E -1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (U.S. liquid)	3.785 412 x E -3	meter^3 (m^3)
inch	2.540 000 x E -2	meter (m)
jerk	1.000 000 x E +9	joule (J)
joule/kilogram (J/kg) radiation dose absorbed	1.000 000	Gray (Gy)
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 x E +3	newton (N)
kip/inch^2 (ksi)	6.894 757 x E +3	kilo pascal (kPa)
ktap	1.000 000 x E +2	newton-second/m^2 (N-s/m^2)
micron	1.000 000 x E -6	meter (m)
mil	2.540 000 x E -5	meter (m)
mile (international)	1.609 344 x E +3	meter (m)
ounce	2.834 952 x E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 x E -1	newton-meter (N-m)
pound-force/inch	1.751 268 x E +2	newton/meter (N/m)
pound-force/foot^2	4.788 026 x E -2	kilo pascal (kPa)
pound-force/inch^2 (psi)	6.894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4.535 924 x E -1	kilogram (kg)
pound-mass-foot^2 (moment of inertia)	4.214 011 x E -2	kilogram-meter^2 (kg-m^2)
pound-mass/foot^3	1.601 846 x E +1	kilogram-meter^3 (kg/m^3)
rad (radiation dose absorbed)	1.000 000 x E -2	**Gray (Gy)
roentgen	2.579 760 x E -4	coulomb/kilogram (C/kg)
shake	1.000 000 x E -8	second (s)
slug	1.459 390 x E +1	kilogram (kg)
torr (mm Hg, 0° C)	1.333 22 x E -1	kilo pascal (kPa)

*The bacquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (GY) is the SI unit of absorbed radiation.

Summary

"The USSR has conducted a total of 527 nuclear tests at the Semipalatinsk Test Site, of which more than 100 were above-ground tests. The affected population counts approximately half a million people."

N.A. Nazarbaev
President of the Republic of Kazakhstan
Kazakhstan Pravda, April 12, 1994

The objective of the present work was to investigate the environmental impact of the nuclear tests at the Semipalatinsk Test Site (STS), also known as the Polygon (see map below). Dosimetric and medical surveys have been conducted at the towns on the periphery of the STS. Nuclide measurements were extended to soil, water, food and fodder.

Medical examinations, which were carried out in the immediate neighborhood of the STS, included therapeutical, instrumental, biochemical, hematological, immunological and other studies. A significant disparity in health status between the subjects and controls (residents of similar settlements remote from the STS) has been established.

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Introduction

In the former Soviet Union, two sites were used for most surface or atmospheric nuclear tests. One of these was at Novaya Zemlya in the Arctic, but the earlier and more used of the two was in what is now the Republic of Kazakhstan. The Semipalatinsk Test Site (STS), or Polygon as it was called, was instituted in 1947. It was formed from three oblasts or provinces: Semipalatinsk (which donated the largest amount of land), Pavlodar, and Karaganda. (Semipalatinsk Oblast has since been incorporated into East Kazakhstan Oblast.) Beginning on August 29, 1949, the former Soviet Union conducted the first of 126 aboveground tests. (This number is cited in the current report; however, according to Dubasov et al. [1], there were only 118.) Thirty of these were surface nuclear explosions, defined by the scaled height ($\overline{h}$) being less than 35. (The scaled height is the height (h) in meters divided by the cube root of the yield (W) in kilotons TNT equivalent.) This included five tests where the nuclear unit failed to trigger; the fuel, however, was scattered around by the conventional explosives. The remaining 88 tests were conducted at much higher scaled heights, where the fireball did not come near the ground and therefore the fallout was much less [1]. Some of these, especially the explosions in 1949, 1951, and 1953, spread more contamination than others.

Data relating to the radiation levels were declassified in 1992 and are published in the first two tables of this report. Basically, the population was exposed to three sources of radiation: acute external gamma irradiation as the plume from the explosion passed over the areas; external gamma (and probably beta) irradiation from the fallout as it settled on the ground and the people themselves; and internal gamma, beta, and small amounts of alpha irradiation from inhalation (directly or indirectly due to resuspension) or ingestion of isotopes that entered the food chain through the vegetation. Dose reconstruction in each of these situations is difficult now and impossible with the first ("cloud shine"), as archived data are often nonexistent.

The authors of this report have relied primarily on archived data for all three scenarios, though fortunately, more recent measurements are available of the extent of ground contamination in some of the populated areas surrounding the STS. Four major expeditions in the late 1950s attempted to ascertain the health status of the inhabitants of some of these villages. In 1989, when the Yeremenko/Tsyb Commission was established to prepare a formal report on the health effects on the population from the nuclear weapons testing program, more health surveys were done. Data from these expeditions were kept at what was then called Dispensary No. 4, a secret institute responsible for collecting health and medical data but which did not provide medical care. Several studies were initiated from these and other data, though most of the reports generated were classified. As part of the present study, the authors conducted surveys of two of the villages most affected by fallout from the tests, Sarzhal and Kainar. A control village, Kokpekty, which was generally similar in ethnic and occupational structure to these two, was selected in an area in eastern Semipalatinsk Oblast that was not affected (or only a little) by the fallout. These surveys were rather detailed, as is apparent in the body of the document. Findings included

cardiovascular irregularities, hyperpigmentation of exposed body parts, keratoses, xerosis, nail dystrophy, and irregular hair loss (patchy alopecia), as well as disorders of most organ systems.

The authors describe in detail a medical condition known as Chronic Radiation Sickness. There are three subtypes of this illness, known as vegetovascular disease, neurocirculatory dystonia, or asthenovegetative syndrome, depending upon its stage and severity. This illness has been described in the literature of Russian medical science [2,3,4] but not in Western literature. This may be due to the fact that exposures to large groups of people of such high doses delivered over relatively long periods of time have not been encountered in the West. Perhaps, however, it is because the presenting symptoms, such as sleep and appetite disturbances, disorders of memory and concentration, and mood changes, are rather “soft”. Physical examination reveals labile blood pressure and weakness, which is difficult to measure. However, functional changes of the nervous system were noted. Distinctly subnormal sensitivity of the olfactory and gustatory senses or heightened threshold of hearing and vestibular dysfunction were evidence for suppressed operation of the central nervous system. White blood counts frequently showed leukopenia, lymphocytopenia, and delayed rate of coagulation. The observed pathology often did not match any more commonly known etiologies.

A monitoring program initiated by the Ministry of Health Dispensary No. 4 in 1972 provided for registration and regular examination of some 20,000 inhabitants of the distressed areas supposed to have been exposed to an estimated 100 mSv, and about 10,000 controls. Published data [5] on external/internal doses at Sarzhal and Kainar cited 1.163/1.3 Sv and 0.271/0.41 Sv, respectively. Compared to controls, doses over 1 Sv were reported to cause doubling of morbidity rates for infectious, endocrine, and hematological diseases and congenital anomalies. In particular, vascular channel and cerebral hemodynamic functions were affected as was the operation of the vegetative nervous system. Peripheral blood counts testified to a hypoplastic state of the blood-producing organs, as revealed by decreased leukocyte count and irregular cell structure. Anemia was found to affect not only the people directly exposed to radiation, but also their descendants. On top of all these conditions, immune dysfunction, autoallergism, and suppression of cellular immunity were recorded. Records also show that malignant tumor lethality exceeded that of controls by more than 40% [6,7].

It is apparent that most of the illnesses described have other potential causes. Poor and often improper diet characterized the population, particularly in view of the tremendous negative social and economic impact of World War II on food availability as well as the entire infrastructure of the largely agrarian economy. Sanitary and hygienic standards were often well below the norm. Medical service to this region, particularly in the rural areas, was often inadequate or even nonexistent. There was insufficient water for household needs, and even the water piped to major cities was inadequate [8]. All of these conditions can affect the health of a population, and many of the health problems described could be attributed to one or more of these factors as well as to radiation exposure.

There is no controversy, however, over the fact that the morbidity in the areas surrounding the Polygon often exceeded morbidity rates in the rest of Kazakhstan or nearby Russia. The relationship of radiation to leukemia and several

solid tissue neoplasms is well known. Nevertheless, association of a given set of illnesses with areas having elevated backgrounds of radiation from fallout does not necessarily imply radiation causation of these illnesses. This investigation was intended to serve as a pilot study to establish whether further research into the health status of these populations and its relation to radiation exposures was warranted. This appears to be the case.

The present study also determined the environmental pollution level in soil, plants, and food 40 years after the initial formation of the basic effective equivalent dose of population irradiation. The health status of the adult population than underwent recorded irradiation during the testing period and two generations of their progeny was defined. The field missions to Sarzhal and Kainar started on 29 June and ended 22 October 1994. The expedition departed for Kokpekty in September 1995, and the laboratory investigations were conducted in October and November. The ethnic composition of these villages is Kazakh with a few Russian families in Sarzhal and Kainar; in Kokpekty 12-15% of the population are Russian, Ukrainian, and German. There is practically no industry. A possible exception might be the dairy business and small meat and milk processing enterprises. The bulk of the population is active mainly in animal husbandry and agriculture. The main crops are wheat and oats.

The treatment and measurement of the samples were performed under laboratory conditions. Integrating the results with data retrieved from the archives, calculations were made of the historical irradiation doses received by the subject populations, with account taken of the dietary habits when computing the internal doses.

Even though it is now ten years since the completion of the study, this report is being published in order to facilitate the dissemination of these very important data and their analysis for critical review and evaluation. It should be stressed that this document, including the collection, presentation, and conclusions derived from the data presented in this document are entirely the work of the authors. Aside from correction of grammatical structure and syntax, and updating of radiation units to SI units, Defense Threat Reduction Agency (DTRA) and its predecessor agencies did not collaborate in the data analysis and preparation of this report. We were especially careful to ensure that editorial changes did not alter the scientific content but only its format and presentability. Consequently, the findings and opinions expressed in this document are entirely those of the authors and do not represent those of the DTRA, the U.S. Department of Defense, or the U.S. Government. Funding and contractual management support for the production and publication of this report was provided by DTRA. The editor is indebted to Dr. Paul K. Blake, Nuclear Test Personnel Review Program, DTRA, who consistently supported the production of these reports. The agency is grateful for the report production and technical editing provided by Chris Brahmstedt of the Defense Threat Reduction Information Analysis Center (DTRIAC), as well as the valuable technical contributions and suggestions provided by William Billado and Don Alderson of DTRIAC for this report.

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Section 1: Introduction and Historical Background

The Semipalatinsk Test Site (STS), or Polygon, was instituted in 1947. Selection of the STS location was probably determined by the proximity of the South Urals military-industrial complex and the sufficiently well-developed transportation infrastructure (the railroad) and Irtish river navigation. A presumably important consideration was the region's relatively sparse population, consisting mainly of Kazakh nationals.

Initially, the labor force was supplied by prisoners, according to the late academician A.D. Sakharov, a well-known human rights activist. What happened to these workers is now unknown. In the 1950s, the convicts were replaced with construction paramilitaries who had built, among other projects, the town of Kurchatov. Kurchatov became the STS administrative center, with a population of some 30,000 of which roughly a sixth worked on the mission. The town, until recently a 'categorized locality' ['secret city,' even the existence of which was classified during the days of the former USSR], incorporated a large complex of research institutions; at present, it accommodates a control center of three operating atomic reactors.

Covering an area of 1,800 km^2, the STS is located at the juncture of three provinces: Semipalatinsk (this province is now part of East Kazakhstan Province), Pavlodar and Karaganda. Lying within the boundaries of the STS are the mountains of Degelen and Myrtyk, which make part of the Sahry-Ahrka Ridge (the Golden Crest), the historic cradle of the steppe civilization founded by the ancient Kipchaks, the ancestors of the present-day Kazakhs. In the 12th-13th centuries A.D., the area formed the core of the state of Deshty Kipchak that subsequently expanded from the River Irtish to the Volga. Sahry-Ahrka, the venerated birthplace of the nation and glorified by bards of many generations, has in the present century become the place of a major nuclear weapons test site.

The total number of tests conducted at the STS with uranium, plutonium and hydrogen devices is 527, which accounts for 70% of all nuclear tests conducted in the USSR; 131 tests were carried out on the Novaya Zemlya island. Out of the STS total, 126 were above ground variety.

The STS activities extended from 29 August 1949 to 19 October 1989. The estimated size of the radiation-affected population is three million people; of these, half are citizens of Kazakhstan, with every third a recipient of a radiation dose exceeding 0.10 Gray (Gy). The other half were in the neighboring Altai region of Russia, where recent estimates indicate a three year decrease in average longevity.

1.1 The STS Tests

1949

The first atomic bomb was tested about 70 km from the city of Kurchatov on 29 August 1949 at 0700. The yield of this weapon, which was an above-ground test, was 20 kt. Contrary to a meteorological forecast that predicted a southwest wind, the lower level wind directions were south and southeast. The radiation cloud therefore moved over the thickly populated areas, including the

town of Kurchatov itself. In the first two hours, the cloud reportedly covered a distance of 70 to 120 km, having passed over, among others, the villages of Budeno, Dolon and Mostyk. As the population had not been alerted (and so took no precautionary measures), every single one of the estimated 80,000 to 100,000 people experienced irradiation, with doses ranging from 1.60 to 2.00 Sv at minimum.

The cloud continued to spread contamination as it moved over the town of Ust-Kamenogorsk, the capital of East Kazakhstan Province, and farther east to Altai Province in SE Russia. The estimate of the initial radiation dose is an average based on our own data, which yield some 2.40-2.60 Sv, and the measurements taken by the STS Dosimetry Service around Dolon and Mostyk, which indicated 1.20 Sv during the first 24 hours after the test. For comparison, the value of the then acceptable ionizing radiation dose was 0.50 Sv, exactly 1,000 times the exposure limit declared safe by the same Ministry of Health a decade later.

The fallout radiation dose was a million-fold times the natural back-ground level. The gamma (γ) radiation dose was 2.00 Gray outdoors, giving at least 65% of the total accumulated dose within the first week. The total dose accumulated by the thyroid gland in adults within the first three months was estimated by the STS Dosimetry service to be 130 mSv; the corresponding dose for the adolescent thyroid gland would be 10 times as high. In the presence of such a source of internal radiation the dose to the gastrointestinal tract and skeleton would be 100 and 240 mSv, respectively, if one takes the tissue-shielding coefficient to be 0.6. The magnitude of the dose to the thyroid gland, using the same coefficient, would be on the order of 300 mSv for adults and 3,000 mSv for children.

The great expanse of the damage caused by the 1949 test was due to the low and far-spreading radiation cloud. In addition to Beskaragai and Zhana Semei districts, the populations of 26 districts located outside of Kazakhstan were also irradiated. The 1989 reconstruction of the cloud's track shows that the cloud moved as far as 500-1,000 km away from the STS.

From the medical angle, the radiation dose received would imply acute radiation sickness of medium severity for a sizeable portion of the irradiated population. Indeed, radiation burns on the face and the uncovered parts of the body as well as alopecia were detected soon afterwards by local health workers examining persons who were working in the open during the passage of the cloud. The residual effects of radiation on the corneous layer of the skin were recorded in Dolon by the research missions of l957 and 1958.

1951

ln 1951, a powerful atomic weapon was tested at the (officially stated) distance of 150 km from the village of Kainar. In the opinion of the villagers, the distance was one-third of this; even now, inquiring visitors are taken to a deep hole (a well) that the local lore associates with the test. The other part of the story, the as yet only source of relevant information, is that beside Kainar, the cloud overlaid the villages of Tailan and Abrala.

1953

On 12 August 1953, a 470 kt yield bomb was tested at an elevation of 100 m.

STS decided to remove the population from the risk fallout area. Based on a forecast of NE-SW wind with a velocity of 40-50 km/h the population inhabiting a 110-120 km deep zone was relocated to a distance of 200 km from the test site. However, the actual velocity of the wind turned out to be twice as high, and its direction changed as the cloud moved. As a consequence, the evacuees, brought together in the village of Karaul, found themselves under the cloud some two to three hours after the explosion. Moreover, for various reasons, the evacuation had not been complete, and a rather large group of people stayed behind; the radiation dose they received was obviously very high, but how high it was may only be guessed for lack of any documentation. The accounts of the witnesses speak of a downfall of gray sticky ash onto clothes thickly covered with dust, of difficulty in breathing, and eye irritation. The skies were overcast and dusk fell; the cattle were restless, and howling dogs, their tails between their legs, would not leave with the departing people. During the day and a half that the withdrawal was performed, the people took food and drink without any precautions.

During the first ten days of the population's return (which took place nine days after the event), the measurements of γ radiation taken in Sarzhal, Karaul and Kainar read 40-60 mR/h, as opposed to the natural background of 15-18 μR/h. The daily dose on the day of return was therefore around 1.5 R, and 10 days later it was still about 1 R. However, a certain percentage of the evacuees had come back even earlier because of anxiety over the state of their livestock.

The radiation dose received by the inhabitants of Sarzhal, Kainar and Karaul over the first week after their return was 0.14 Gy, which would give a monthly and quarterly dose of 0.34 and 0.64 Gy respectively. The yearly dose would be consequently about 0.80 Gy. These estimates are from Dr. Boris I. Gusev, Director of the Kazakh Scientific-Research Institute of Radiology and Ecology. Dr. Gusev also concluded that the dose received by the thyroid gland, the gastrointestinal tract and the skeleton from radionuclides that entered the organism during the first three months via food, drink and breathing should have been 24, 10-12 and 2-3 mSv, respectively.

Later Tests

Contamination of an incomparably more extensive area, in fact comprising the better part of Semipalatinsk Province, must have ensued during the tests that followed. The STS files, however, contain records of only 12 tests, namely the tests that took place in 1951, 1953, 1954, 1955 (2), 1956, 1957, 1958, 1960 and 1962. During this period of time, 96 atmospheric and 26 above-ground tests were performed.

According to S.L. Turapin, a retired colonel involved in the USSR's nuclear test program, testing of plutonium devices yielding up to 16 kt was begun in 1953; the cloud drifted toward Kainar, Tailan and Eguindy Bulak. The next year a plutonium bomb with a 6 kt yield was tested, and the test was repeated in 1955; both explosions were above ground. In 1955, testing was unsuccessful, though radiation did leak out with sufficient force so that traces were noted in cities of East Kazakhstan Province, some 300 km from the STS. The highest rate of tests, a total of 30 in one month's time, was noted in March 1958, short-

ly before the top-level Soviet-American negotiations. No data on the radiation consequences of these tests have yet come to light.

1.2 Ionizing Radiation Doses

During Above-Ground Testing

In 1992, the STS authorities had to comply with the demand of the Kazakh Government to declassify the files relating to the STS-generated radiation levels in Semipalatinsk Province. The information that was supplied was a selection of data on the 12 tests referred to above; information on the underground tests and associated environmental contamination was not included. The information that we were able to gather from the declassified files on the contamination history of the area around the STS is presented in Table A1 in the Appendix.

A comment on the STS policy toward radiation protection of the population is in order. One reason why, by present standards, relatively little with regard to this aspect of nuclear testing was done is that the Ministry of Health initially considered an annual cumulative dose of 50 rem to be an acceptable level. Accordingly the people of the village of Kainar were exposed to fallout five times during the period between 1951 and 1955 (see Table 1).

lt should be noted, on the other hand, that making forecasts about the post-explosion events is by no means a trivial undertaking. Ability to predict formation and proliferation of radioactive products in the atmosphere requires a lot of research. The STS researchers were primarily focused on the study of the strike force produced by radiation and the blast wave.

Table 1. Levels of Radiation Contamination from Nuclear Testing Around the STS During 1949-1962

Locale	Distance from epicenter (km)	Dose rate during measurement (R/hr)	Time between explosion and measurement (hours)	Duration of fallout (hours)	Total γ dose on the surface (R)	Total γ dose on the population (R)
1949 Test: 20 kt above ground						
Beskaragai Region						
Budeno	98		165	3.6	256	180
Dolon	118	0.12	173	3.4	200,224*	160,134*
Cheriomushky	76		173	3.0	167	110,100*
Mostyk	90		173	3.4	157	110,90*
Kanonerka	129				175	114,112*
Novo-Nikolaevka	162				34	22
Undyrzh	147				19	15
Ramadan	120				29	16
B-Vladimir	120				36	21

Table 1. (Continued)

Locale	Distance from epicenter (km)	Dose rate during measurement (R/hr)	Time between explosion and measurement (hours)	Duration of fallout (hours)	Total γ dose on the surface (R)	Total γ dose on the population (R)
Grachy	79				14	7
Topolena	75				14	9
Belokamenka	122	0.000036	173	3.4	6	5
Baidaulet	62				21	16
Zhana-Semei Region						
Glukhovka	138				6	7,4*
Turkai	136				6	7,4*
Sotzialisti-cheskoy	129				6	7,4*
Borodulikha Region						
Borodulikha	147				14	12,11*
Dmitriyevka	141				16	13,12*
Kamyshenky	153				11	10,9*
Petropavlovka	161				10	8,7*
Mikhailenkova	161				7	7,5*
Novo-Shulybeksky Region						
Novo-Shulybek	212	0.00016	275	14.2	5.3	14,8*
Peschanka	216				6	7,5*
Proletarka	234				5.2	7,4*
Altai Territory						
Lokot	240	0.016	220	6	31	27,24*
Kurya	340	0.0036	227	8.5	6.5	15,6*
Petropavlovskoye	480	0.00029	255	12	1.6	0.6
Solton	653	0.00011	390	16.3	0.3	0.2
1951 Test						
Abai Region						
Kainar	150	0.27	10	10	49	39,37*
Kolkhoz Molotov	225	0.17	20	15	14	12,11*
Teskesken	410	0.004	20	27	0.3	0.2
Tespakan	460	0.002	20	31	0.12	0.1
Bestamap	211	0.11	20	15	13	12
Kzltas	231	0.14	26	20	9	9,7*
Ushbaik	236	0.11	29	23	7	9,5*
Akshatau	261	0.09	32	16	4	5,4*

Table 1. (Continued)

Locale	Distance from epicenter (km)	Dose rate during measurement (R/hr)	Time between explosion and measurement (hours)	Duration of fallout (hours)	Total γ dose on the surface (R)	Total γ dose on the population (R)
1953 Test						
Abai Region						
Tailan	100	3	36.6	1.2	1000	
Sarzhal	110	1.19	25.7	1.3	250	100,42*
Karaul	200	0.18	84	2.4	150	100,37*
Kainar	150	0.9	35.6	1.3	150	100,43*
Konis	151	0.17	3	4.57	2	1.2
Kaskobulak	160	0.47	3	5.78	4.1	2.1
Kzitas	112	0.59	3	3.96	7.2	4.5
Zhana-Semei Region						
Znamenka	98	1.2	37.6	1.8	120	70
Terstambal	112				40	34,28*
Klementievo	126				14	12,10*
Sarapan	90	1.34	26	2.4	250	100,65*
Isa	89	1.34	26.5	1.6	250	100,98*
Charsk Region						
Charsk	203	1.7	90	2.4	10	9,7*
Suhuk-Bulak	179	0.6	95	2.6	9	9,7*
Bakarchik	215	0.3	95	1.7	10	9,7*
Angirzhal	300	0.04	25.6	3.5	0.6	5
Ayauz Region						
Ayauz	350	2.3	75	3.3	14	12,11*
Zhirma Region						
Zhirma	262	0.8	112	3.1	7	6,4*
Chibartau	198	0.69	109	2.1	1.2	11,9*
1954 Test						
Kainar	117	0.22	3	3.54	2.7	1.3
Kzil-Adir	111	0.59	3	3.96	7.2	4.5
Kaska-Bulak	160	0.47	3	5.78	4.1	2.1
Sovkhoz Charsk	237	0.21	3	8.5	2.2	1.2
Sovkhoz						
Kaban-Chukur	327	0.1	3	11.7	1.0	1.0
Zharma	262	0.8	112	3.1	7	6,4*
Kapan-Bulak	270	0.6	118	1.2	9	9,6*
Sovkhoz Konaz	151	0.17	3	4.57	2	1.2

Table 1. (Continued)

Locale	Distance from epicenter (km)	Dose rate during measurement (R/hr)	Time between explosion and measurement (hours)	Duration of fallout (hours)	Total γ dose on the surface (R)	Total γ dose on the population (R)
Sovkhoz						
Kaska-Bulak	160	0.6	3	6.5	6.5	3.2
1955 Test						
Kainar**	98	0.31	3	2.8	4.1	3.5
Kainar**	128	0.18	3	3.7	12.2	10.1
Znamenka	98	0.51	3.5	3.1	19.3	21,15*
Balterek	111	0.72	4.6	3.8	12.2	12,7*
Repinka	134	0.26	3.1	4.52	14	10
1956 Test						
Isa	89	0.0014	720	1.7	15	13,12*
Znamenka	98	0.0003	720	2.2	3	3,20*
Novo-Shulba	212				8	9,6*
Borodulikha	147				14	12,10*
Karasu	244	0.0002	720	4.1	1.7	
Borodino	263	0.0008	720	4.4	6.8	
Akimovka	335	0.0018	720	5.6	13	
Ust-Kamenogorsk	342	0.0016	720	5.7	10	18
Tarkhanka	364	0.0003	720	6.8	2.4	2.0
Borovka	345	0.0003	720	5.8	2.4	2.0
1957 Test						
Znamenka	98				35	37,30*
Kolkhoz 30 Years of Kazakhstan	90	0.05	8		8	2,1.5*
1958 Test						
Sarzhal	110				21	38,19*
Charsk	203				6.3	11,8*
Oktyabrsk	189				5.4	8,5*
Zharma	262			1.2		7,5*
East Kazakhstan Province						
Borodino	263	0.0008	720	4.4	6.8	9,5*
Akimovka	335	0.0017	720	5.6	13	13,11*
Ust-Kamenogorsk	342	0.0016	720	5.7	10	18
Tarkhanka	364	0.00031	720	6.8	2.4	2
Borovka	345	0.0007	720	5.8	2.4	2

Table 1. (Continued)

Locale	Distance from epicenter (km)	Dose rate during measurement (R/hr)	Time between explosion and measurement (hours)	Duration of fallout (hours)	Total γ dose on the surface (R)	Total γ dose on the population (R)
1960 Test						
Zhana-Semei Region						
Terstanbali	112				10	11,8*
Semenovka	114	0.22	3	3.6	2.4	7,3*
Topolka	75				1.5	2
1962 Test						
Semenovka	114				2	6,2*
Topolka	75				1.8	2.3
Dolon	118				15	14,11*
Semipalatinsk	137				0.9	5,3.2*
Kokpekty	290				0.3	0.2
Bolshaya Lukon	320				0.25	0.2
Aksaut	390				0.03	0.2
Urdzhar	570				0.003	0.3,0.15*
Makanchy	750				0.002	0.25,0.11*

Source: Data were obtained from the USSR Ministry of Defense in response to a request from President N.A. Nazarbaev of Kazakhstan

Note: Included in the table are the data for the tracts of land lying along the known tracks of radioactive clouds and for regions that feature accumulated outdoor γ radiation doses in excess of 1 R. The STS records provide no information on the delay time between tests and γ radiation measurements. Similarly, neither the cloud's arrival time, nor the wind velocity or cloud elevation are indicated. Also, information on radioactive precipitates fallout and radiation doses received at other population centers is lacking.

* Values separated by commas indicate the results of two or three different sources in the area, but by the same physicist-dosimetrist.

** During the year 1955, Kainar was subjected to two different tests. The readings for each test were taken at different places near Kainar, hence the discrepancy in distances from the hypocenter.

1.3 Measurement Techniques

Information as to how the personnel of the STS Dosimetry Service went about their job has been provided by Colonel Turapin, the division's chief for 12 years. The measurements were usually taken using dosimetric equipment mounted on board a plane making trips round the moving radioactive cloud. Because the pilots were certainly wary of going deep inside the clouds, most dosimetric data would be valid for the periphery.

Radioactivity was measured using filters of various diameters. The Petryanov filters that were used are normally employed to collect soot exiting from power-plant stacks. In Colonel Turapin's opinion, the efficiency of the filters as collectors of variously sized radioactive particles was far too low: there is a significant difference between soot particles and the radioactive particles that form as a result of a nuclear explosion. While weakly charged soot particles are effectively trapped at the surface, the radioactive particles have a charge that allows them to pass through the filter grid. The hypothesis requires experimental verification, but at the same time it provides at least some explanation as to why the STS readings were much too low. Colonel Turapin was anyway convinced that he had a clue to the mystery and he reported his discovery to a Central Committee's department in charge of national defense, with a result that he was sent to retirement and his calculations of the "true" radiation doses were so thoroughly eradicated that no trace of them has ever been found to date.

The data presented in Table 1 are limited to only ten STS tests. Moreover the underlying principle (if any) of dosimetric sampling defies analysis. In the case of the 1956 event, for instance, the readings were taken east and southeast of the STS (Borodulikha, 150 km and Nova Shulba, 212 km) and for some unknown reason also in Ust Kamenogorsk, 350 km, which lies directly east of the STS. If that implies the expanse of the cloud, then one has to conclude that no readings were taken between these points.

Accumulated ionizing radiation doses for selected areas around the STS are given in Table 2. It can be seen that the village of Kainar experienced six radiation events, with the total radiation dose reaching 2.10 Gy. A smaller number of exposures but a higher total dose - 2.88 Gy for two events - was experienced by the villagers of Sarzhal.

Table 2. External Radiation Doses (rad) Around the STS. (outdoor/indoor readings).

District	Village	1949	1951	1953	1954	1955	1958	Total
Abai	Kainar	--	40/39	150/100	2.7/1.3	4.1/3.5		210/151
						12.9/10.1 *		
	Tailan			1,000/--				1,000/--
	Sarzhal			250/100			38/21	288/121
	Karaul			150/100				150/100
Beskar-agai	Bodene	256/180						256/180
	Dolon	200/160						200/160
	Kanonerka	175/114						175/114
Borodu-likha	Korostely	16/13						16/13
	Moshchanka							
Zhana Semei	Znamenka			120/70		21/19		144/93
						3/3		
	Sarapan			250/100				250/100

Table 2. (Continued)

District	Village	1949	1951	1953	1954	1955	1958	Total
(control)	Kokpekty		7/4					7/4

* There were two different tests in 1955 affecting Kainar.
Source: the No. 4 Dispensary.

Basically, three radiation exposure scenarios can be envisioned. The first is acute external γ-ray irradiation as radioactive clouds passed over the population centers without delivering fallout. This possibility can only be noted, since all exposure data are based on land dosimetric measurements taken after the plumes had passed and largely dissipated.

Secondly, there is exposure to high doses of γ-radiation, caused by a combination of an air-borne source and a load of descending radioactive debris. The inevitable consequence of such events would be chronic internal irradiation via food, drink and inhaled air. The third scenario is therefore chronic internal irradiation caused by the particles contained in the contaminated food and drink. This mode of exposure would be typical for those who moved into the areas around the STS after 1965.

Assessment of the health risk from internal irradiation was one priority the government of Kazakhstan pursued in its declassification drive. At the time it was unclear whether the relevant data constituted classified matter or simply had never been gathered. It turned out in the end that the latter was the case. In an effort to comply, the military presented the declassified external irradiation information together with their calculated estimates of the corresponding internal irradiation levels. A selection of these, bearing on the population centers of interest in the context of the present study, is given in Table 3.

Table 3. External and internal radiation doses (rad) around the STS.

Districts	Villages	External	Internal	Total
Zhana Semei	Aktogai	66.8	96.0	162.8
	Zagotskot	50.2	73.0	123.2
	Znamenskoe	5.17	1.5	6.67
Abai	Kainar	27.2	41.0	68.2
	Karakora	23.5	27.6	51.1
	Karaul	35.8	52.0	87.8
	Sarzhal	116.3	130.0	246.0
Beskaragai	Bodene	167.9	180.0	347.9
	Dolon	217.4	230.0	447.4
	Kanonerka	84.1	95.0	179.0
Borodulikha	Korostely	102.2	140.0	242.2
	Meshchanka	40.8	50.0	90.8
Kokpekty	No data			
(control)				

Table 3 summarizes the findings of a State Committee which was set up in 1992 to study the data delivered by the STS Dosimetry Service. A multi-disciplinary body, the Committee was comprised of ecologists and health workers. Undoubtedly a piece of careful analysis and sound judgment, the Committee's work is only useful to the extent to which the summary tables and isobaric processes on which it is based can help in reconstructing the actual contamination history. The log books containing the readings of primary dosimetric measurements were never made available to the Committee. Conclusions made by the Committee can be regarded therefore as neither definite nor final.

Specifically, internal radiation doses received by the populations around the STS have been determined only approximately by using the known calculation techniques and with no account taken of the peculiarities relating to landscape, diet, and so forth, or to the fact that the worst polluting tests of 1949, 1953 and 1955 took place in the month of August, the harvest and hay-making time.

Another consideration left out of the Committee's calculations is that the evacuation of the population from the area of anticipated heavy fallout was implemented only once, in 1953, and even then the withdrawal was suboptimal. There are also some inconsistencies in the data from the STS. For example, according to Table 2, the internal radiation dose received by the inhabitants of Kainar was 0.682 Gy of which a mere 0.272 Gy was due to the external γ radiation. It is, however, well known that in consequence of five exposure events the villagers of Kainar experienced total doses of internal and external radiation that were, respectively, 2.10 and 1.50 Gy.

1.4 Peaceful Nuclear Explosions

The ban on above-ground nuclear tests did not end the contaminating of the Semipalatinsk region with nuclear debris. The first contamination episode after the 1963 Treaty occurred in January 1965 when a nuclear charge was used in constructing a pit and dam ensemble at the convergence of the Nizisu and Chagan rivers, in the Zhana Semei district. The explosion itself was made well under the ground, at a depth required by the excavation target, but the blast also caused an enormous quantity of radioactive material to break out and, at a relatively low elevation, grow into a radioactive cloud of considerable volume. The track of the cloud's movement lay across the Zhana Semei and Abai districts. The dosimetric measurements conducted in the villages of Znamenka, Isa, Sarapan and Dembegetel read 20 to 30 R.

A similar event took place in 1974. Apparently an underground test accident, it led to extensive contamination with an estimated radiation level of 10-15 R/hr.

The consequences of the 1965 fallout were made the object of a study which was undertaken by the Radiological Department of the Semipalatinsk Regional Veterinary Service. The data from measuring the radioactivity in the milk are given in Table 4.

Table 4. Radioactive Contamination of the Milk Following the 1965 Explosion.

Pasture location	Time between event and measurement	I-131 level (pCi/l)	(Bq/l)
Sovkhoz Zhamenskoe	15 days	900-3,700	33-137
Sovkhoz Dolonsky	20 days	870-5,800	32-215
Sovkhoz XX Partsiezda	2 months	200-3,400	7-126
(in Borodulikha Distr.)			
Sarapan (Sarzhal)	26 days	9,000-85,000	330-3185
Similar measurements of Strontium-90 yielded the following data:			
Watering places	3.9E-9 Ci/l (144 Bq/l)		
Pastures	1.3E-9 Ci/l (48 Bq/l)		
Bones			
Beef	2.87E-7 Ci/kg (10.6 kBq/kg)		
Sheep	5.3E-8 Ci/kg (2.1 kBq/kg)		
Horses	9.4E-8 Ci/kg (3.5 kBq/kg)		
On the estate of the cattle-breeding farm Degelen, where hay was stored up in summertime and where the cattle-breeders stayed for 4 to 5 months, the stored hay had the following radionuclide profile:			
Sr-90	2,005 pCi/kg (74.2 Bq/kg)		
Cs-137	646 pCi/kg (23.9 Bq/kg)		
Pb-210	2720 pCi/kg (101 Bq/kg)		
Dosimetry of beef produced at Sarapan revealed the following contamination levels:			
Sr-90:	320 pCi/kg (11.8 Bq/kg)		
Cs-137:	57 pCi/kg (2.1 Bq/kg)		
Pb-210:	36 pCi/kg (1.3 Bq/kg), but a much higher level of 182 pCi/kg (6.7 Bq/kg) for liver and kidneys.		
The horse meat contained 48.7 pCi/kg (1.80 Bq/kg) of Sr-90 and 71.7 pCi/kg (2.65 Bq/kg) for Pb-210, whereas the respective concentrations for horse bones were 16.3627 and 0.3664 pCi/kg (605 and 13.6 mBq/kg).			
Measurements taken in the village of Sarapan years later indicated that the isotope's content was still high:			
Hay	1.00E-7 Ci/kg (3.68 kBq/kg)		
Meat	to 200 pCi/kg (7.4 Bq/kg)		
Milk, cow	80 - 120 pCi/kg (3.0-4.4 Bq/kg)		
Milk, horse (koomys)	50 - 70 pCi/kg (1.85-2.6 Bq/kg)		

Cooking reduces the presence of Sr-90 and Pb-210 [in the bones] to less than one-tenth of the original concentration, though the concentration in the

broth will increase the longer the cooking process continues. Thus, 2 liters of broth made from horse bones containing 605 mBq/kg Sr-90 and 13.6 mBq/kg Pb-210 should have these isotopes at concentrations of 296 and 685 Bq/kg, respectively. Measurements of Strontium-90 and Lead-210 levels in drinking water showed that these were usually within 1.48 and 2.85 Bq/l respectively. It is frequently maintained that natural decay of U-238 does not lead to Pb-210; however, in the context of nuclear testing, one deals with fission products, not decay of U-238.

Three years after its creation in 1965, the artificial lake and its banks were dosimetered to find that the average radioactivity level was at 50 mR/h with a level three times lower (17 mR/hr) at the northern and northwestern end of the water basin. The fish contained 63.3 Bq/kg of Sr-90 in 1967 and 14.8 Bq/kg in 1971. The Cs-31 dosimetry, which was first measured in 1971, gave 3.33 Bq/kg. Even though these levels fall within the allowed limits, they appear to be raised 100-fold compared with the fish in noncontaminated reservoirs.

The findings of follow-up dosimetry in 1981 and 1982 detected Ce-144 at the following concentrations:

Soil	1,500 pCi/kg (55.5 Bq/kg)
Hay	3,400 pCi/kg (126 Bq/kg)
Straw	350 pCi/kg (13.0 Bq/kg)

An object of concern is the appearance of radioactive Pb-210 in the fallout upon Semipalatinsk Province.

1984	1.98 mCi/km^2	73 MBq/km^2
1986	2.85 mCi/km^2	105 MBq/km^2
1987	3.12 mCi/km^2	115 MBq/km^2
1988	3.91 mCi/km^2	145 MBq/km^2

However, this may be misleading, as the radiological department of the Veterinary Service measured only the sum total of α radiation. Mass spectrometry was not routinely performed. Moreover, as it was forbidden at that time to mention plutonium, all α radiation was attributed to lead. It is possible, too, that a very small amount of the increase after April 1986 might be due to fallout from Chernobyl.

At Znamenskoe, in the Zhana Semei region, the hay contained 1,100 pCi/kg (40.7 Bq/kg) of Pb-210. A more extensive dosimetry conducted at Dolon came up with the following assessment:

Fodder corn	40-50 pCi/kg (1.5-1.85 Bq/kg)
Hay	2,200 pCi/kg (81.4 Bq/kg)
Milk	2-5 pCi/kg (0.74-0.185 Bq/kg)
Meat	10-20 pCi/kg (0.37-0.74 Bq/kg)
Bones	3,900 pCi/kg (144 Bq/kg)

The consequences of the 1974 contamination event have also been evaluated. On the 17th day after the accident, the total pasture β radioactivity was 2.7 x 10-7 Ci/kg (9,990 Bq/kg) with the elemental composition and corresponding doses being as follows:

Sr-90	3160 pCi/kg (117 Bq/kg)
Cs-137	2,550 pCi/kg (94.4 Bq/kg)
I-131	4,650 pCi/kg (172 Bq/kg)

Based on these data, the initial corresponding I-131 doses for the grass and the milk would have been 30,000 and 160 pCi/kg (1,110 and 5.92 Bq/kg) respectively. The atmosphere would additionally have contained Kr-85 with a half-life of 10.7 years.

The presence of α radionuclides was suggested by a radiochemical study conducted in the affected area in 1976. The level of Po-210, in particular, was determined for bovine and ovine skeleton and found to be, respectively, 400 and 1,000 pCi/kg (14.8 and 37 Bq/kg).

1.5 Underground Tests

Available data suggest that accidents accompanied by outbursts of radiation onto the ground and into the atmosphere took place for various reasons in the 1965, 1974, 1985, 1987 and 1989 underground tests. In 1987 alone, there were as many as six emissions of radioactive gases, with each producing a radiation level ranging from 50 to 500 μR/h (0.5 to 5 μGy/hr).

A significant upsurge of environmental radioactivity occurred in 1974 following the May 25 test. The most affected area was the village of Sarzhal and environs. The total β activity reached 2.7 x 10^{-7} Ci/kg (10 MBq/kg) of the green mass. The I-131 content of milk was 160 pCi/l (5.92 Bq/l). Still higher concentrations were recorded for the fodder, where Ce-144 and Sr-90 levels were found to be 3400 and 1300 pCi/kg (126 and 48 Bq/kg), respectively. The content of the latter element in the major ethnic Kazakh dietary dairy product koomys (fermented mare's milk) was 153 pCi/l (5.66 Bq/l).

Radiation monitoring data for the Semipalatinsk region in 1987-1989 reveal three peaks in the γ radiation profile. The highest peak of 350 μR/h occurred in the town of Semipalatinsk on 7 May 1987; the second peak of some 45 μR/h was recorded on 18 September of the same year. The last peak, on 13 February 1989, was in effect an aftermath of underground testing, detected 3 days after the event in the township of Bolshaya Vladimirovka as an increase in γ radiation level to 170 μR/h there and to 1,600-2,000 μR/h in the village of Chagan. Since 1980, the background γ radiation value had usually been 35-40 μR/h.

Until 1985, background γ radiation measurements had, as a general rule, been taken by STS personnel, and the results of the measurements were not supposed to be made public. The opportunity for citizens to make their own measurements arose with the availability of consumer dosimeters such as the SPR-18. The results of some of these measurements, from the precipitation in the region during 1985-1989, are given in Table 5.

Table 5. Radioactivity Measured in Precipitation in Semipalatinsk Province, 1985-89.

Year	Total precipitation* (mm)	Radioactivity (Ci/km²)
1985	253.2	48.4×10^{-4} (179 MBq/km²)
1986	513.1	639.3×10^{-4} (2,365 MBq/km²)
1987	324.7	128.5×10^{-4} (475.5 MBq/km²)
1988	297.6	90.9×10^{-4} (336 MBq/km²)
1989	274.0	76.5×10^{-4} (283 MBq/km²)

* Total precipitation is for the entire province; measurements of radioactivity were taken at different locations by different persons (see text).

The official number of underground tests through 1989 was 400. A study of the consequences of these tests would readily show that their associated environmental and seismic risks were posing a real threat to the health and well-being of the neighboring populations. Unfortunately, the shroud of secrecy that the military had spread over the STS also covered the health and safety risks to the population surrounding the site. After the secrecy was lifted, there were few data pertinent to these risks. It is quite probable that the reason why the military were unable to come up with their records after these were declassified is simply that there was no information to be presented for examination.

1.6 Dosimetric Studies

Turning back to the times of the information ban, the most barren decade in this respect was the 1950s. The efforts of the Kazakh Academy of Sciences to penetrate the secrecy barrier put up by the military were to be seconded by the Institute of Biophysics of the Ministry of Health of the USSR. On an expedition organized by this Institute in 1960, a radiology team of the local Academy of Sciences managed to survey a number of population centers around the STS. The radiation levels they discovered were 1.34 Gy in Dolon, 0.42 Gy in Sarzhal, and 0.10 and 0.07 Gy, respectively, in Karaul and Kainar.

The field data gathered by the expedition have since been reviewed twice; each time the exposure levels were raised. The recalculated external radiation data reported by Colonel Turapin in 1989 showed 1.60 Gy for Dolon, 0.557 Gy for Sarzhal, 0.415 Gy for Kainar and 0.302 Gy for Karaul. The corresponding values obtained by Dr. Boris I. Gusev, the Surgeon-in-Chief of the No. 4 Specialized Dispensary, were 2.00/1.60, 2.88/1.21, 2.10/1.51 and 1.50/1.00, where the slash separates the outdoor values from the indoor values (or, alternatively, designates the allowance made for the evacuation).

Although the archives did feature some unsystematically compiled data on Sarzhal (Appendix Table A2), Tailan, and the control Kokpekty, unfortunately, there were no records on Kainar whatsoever. The biggest file dealt with the Sarzhal soil samples that were studied between 1981 and 1992 (Table A3); it shows that the Cs-137 concentration ranged from 14.92 to 80.3 Bq/kg. However, the record made on 28 April 1981 gives the value of 524.0 Bq/kg. Additionally, the file contains the Ru-103 and Ru-106 data. As to the Cs-137 content in plants, the highest value of 163 Bq/kg was recorded on 12 May 1987.

The soils of Sarzhal were also studied by an expedition from the Kazakh Academy of Sciences in 1958 and found to show little variation in radioactivity level with depth, the values determined for 5 cm and 15 cm deep layers being, respectively, 16.7 and 13.8 Ci/km^2.

The highest Cs-137 value recorded for the soils of Tailan (Table 5) is 7,326 to 8,436 Bq/kg, with the presence of Co-60 also. The concentrations of I-131 and I-132 in plants reached 3,633 and 2,297 Bq/kg, respectively. Comparison with the control data gathered for the same nuclides in Kokpekty (Table 6) makes a strong case for a relatively recent STS-induced local contamination that added onto the global pollution. Support for this conjecture comes from the 6.2 ratio of Sr-90 content in bones between Sarzhal and Kokpekty.

1.7 Summary

In conclusion, it should be noted that exact information on the individual and collective radiation doses received by the affected populations may probably never be available, since nothing like a proper dosimetric record has ever been maintained. The calculation method used in reconstructing the past radiological situations may, for all its usefulness, be subject - as we tried to show - to significant error. Yet, as one surveys the period between 1949 and 1989, two aspects of the radiation exposures experienced by the population as a result of weapon testing at the STS stand out:

- The role of the radioactive clouds as major sources of intense radiation
- Periodic acute radiation exposures due to surface leaks of radioactive gases from underground weapons tests

Additionally a description of the present-day radiological situation in the Semipalatinsk region should include the continual internal irradiation of the population by radioactive substances.

The ground and air nuclear tests conducted at the STS led to contaminating a large area covering four (now three, as Semipalatinsk and East Kazakhstan Provinces have been combined into one East Kazakhstan Province) provinces in Kazakhstan (Semipalatinsk, Karaganda, Pavlodar and East Kazakhstan) and the area occupied by Altai Province in the Russian Federation. With respect to the radiation levels on record, the affected area can be divided into the following four zones:

- Extremely high radiation risk. The zone would include the Abai, Abralin (until 1953 when it was disbanded), Zhana Semei, and Beskaragai districts of Semipalatinsk Province. The level of outdoor external ionizing radiation here was between 160 and 260 R, reaching a maximum of 502 R in the locality of Karakork. The number of irradiated people was 60 to 80 thousand. The effective equivalent dose was 2.00 – 4.42 Gy. The radiation victims were the inhabitants of the following population centers: Budene, Dolon, Cheromushky, Mostyk, Sarzhal, Isa, Sarapan, Karakork and Zagotskot-2.
- High radiation risk. This zone extends across the Abai, (Abralin), Beskaragai and Zhana Semei districts. The level of the radiation here lies within the 0.35 – 1.00 Gy range.

- Heightened radiation risk. Living within this zone are the population centers of Nova Shulbino, Borodulikha, Charsk, Semipalatinsk city and the Zharma and Ayaguz districts. The effective equivalent dose here measures 0.10 to 0.35 Gy.
- Low radiation risk. The zone covers Makhanguin, Urdtar, Taskenpen, Aksuat and the Kokpekty districts of Semipalatinsk Province. The effective equivalent dose here lies between 0.001 and 0.10 Gy.

The effects on the radioecological situation in Semipalatinsk Province within a 200-250 km radius of the epicenters of the explosions at the Polygon were chiefly from surface tests carried out between 1949-1962 without taking protective measures. These included the tests of 29 August 1949, 24 September 1951, 12 August 1953 (thermonuclear), and 10 May 1956 (hydrogen); the effects of these explosions extended to Eastern Kazakhstan Province.

1.8 STS-Generated Health Effects

In its medical and public health aspects, the situation in the Semipalatinsk region between 1949 and 1989 is unprecedented in world history. Acute, subacute, and chronic radiation exposures occurred continuously and in various combinations, giving rise almost every year to new radiation risk groups and multiplying sufferers from internal as well as external radiation.

The data to date yield two phases in the evolution of the adverse health effects produced by the STS-generated radiation. The initial phase spans 1949 through 1960. During this interval, the radiation exposure effects were assuming their full medical and demographic nature. Typical manifestations were clinical acute/subacute radiation sickness (the Kainar Syndrome), raised levels of morbidity for most infectious diseases, and increased rates for adult, infant, and prenatal mortality.

In the next phase, which extends from 1960 to the present, acute radiation sickness has abated, and remote adverse health effects appear. They are remote both in the temporal sense and in the sense that they are affecting succeeding generations. Their major manifestation is a permanently raised level of mortality that began rising 5 to 8 years after the initial exposure and still shows no signs of reversing.

1.9 Case Studies

Confining their functions to implementing the government's weapons testing program, the STS leadership avoided any commitment to making the health effects of STS activities a specific subject for study. Therefore all of the studies pertaining to the health effects of the weapons testing program that have been derived from organizations other than the STS. The following four major studies have been carried out:

- A clinical exploratory program under the guidance of Professors S. Balmukhanov and B. Atchabarov, performed during the expeditions sent by the Academy of Sciences of the Republic of Kazakhstan to six districts of Semipalatinsk Province in 1954 through 1959.
- A sample population health monitoring program initiated in 1964 and implemented by a closed military institution bearing the designation of No. 4 Specialized Dispensary.

- A 30-day case sample study conducted in 1989 by an interdepartmental commission led by Professor Anatoli F. Tsyb.
- A medical surveillance program now in progress in Semipalatisk Province, a joint effort of Semipalatinsk Medical School and the recently established Kazakh Scientific-Research Institute for Radiation Medicine and Ecology.

1.10 The Balmukhanov-Atchabarov Expeditions

A case-control study involving 6,000 adult inhabitants of three exposed districts - Abai, Beskaragai and Eguindy Bulak - and three control districts - Chubar Tau, Bayan Aul and Ulu Tau - was conducted under the auspices of the Kazakh Academy of Sciences over a period of several years beginning in 1954.

The geographical distribution together with some primary data on the case and control groups examined during 1958-1959 are presented in Table 6. The case and control subjects were similar in ethnic composition, occupation, and social status.

Table 6. Geographical Distribution and Morbidity Percentages of Case and Control Subjects, 1958 and 1959.

	1958		1959	
Locale	**Number of subjects**	**Morbidity (percent)**	**Number of subjects**	**Morbidity (percent)**
Abai				
Kainar	458	46.7	356	54.9
Sarzhal	377	53.6	358	57.4
Karaul	542	38.4		
Chubar Tau				
Barshatas (control)	482	25.6		
Ulu Tau				
Ulu Tau (control)	572	8.6		
Beskaragai				
Dolon I *			369	29.9
Dolon II *			108	5.5
Bayan Aulsk				
Shchadra (control)			414	14.9

* Dolon I includes the permanent residents who were subjected to irradiation in August 1949. Dolon II includes people who were moved to this settlement after 1956, owing to conversion of pastoral lands for agricultural purposes. Dolon II was established in 1963.

Clinical symptoms of radiation pathology such as hemorrhagic diathesis, anemia, and leukopenia/lymphopenia were found to be frequent in Abai and Beskaragai. A markedly increased incidence of asthenovegetative syndrome and arterial hypertension were also noted, whereas brucellosis, among other contagious diseases, displayed clinical peculiarities, unusually high severity, and refractoriness to treatment. In contrast, the occurrence of these peculiarities was rare in Chubar Tau and almost nonexistent in Ulu Tau, at a distance of some 600 km from the STS.

Documentation consisted of outpatient clinical records. Brucellosis and tuberculosis patients were excluded from the sample. A singular condition of the oral cavity and genital mucosa was observed, with constellations of hemorrhagic diathesis patches or papules. Hyperemic conjuctivas and excessive gum bleeding also were observed. The skin and its appendages displayed unknown or rare symptoms, which can be grouped according to their nature as follows: deficient skin nutrition, (atrophy/dystrophy of hair, alopecia, premature graying), aberrant pigmentation, and corneum anomalies (dyschromia, vitiligo, hyperkeratosis, ichthyosis). Statistical treatment of the observed results is presented in Table 7.

Table 7. Incidence of Skin and Corneum Disorders in Contaminated and Uncontaminated Populations*, 1957-58 (percent of the sample) (1957-1958).

	Contaminated			**Uncontaminated**	
Symptom	Kainar	Sarzhal	Dolon I	Dolon II	Shchadra
Hyperpigmentation	53.5	20.6	40.1	18.0	4.3
Skin Hyperkeratosis	10.5	9.8	9.4	2.1	1.0
Xerosis	17.0	9.6	14.1	9.1	0.2
Cheilitis	17.6	9.4	16.0	9.0	0.4
Hair: Patchy Alopecia					
Loss/Brittleness	5.8	2.4	3.1	1.5	1.7
Nails: Desiccation					
Cracks/Brittleness	6.2	7.3	3.4	1.4	2.0
Trivial Dermatitides	7.9	10.1	12.2	13.1	14.6

* These are arranged in order of distance from the Polygon test sites.

Epistaxis featured high among the subjects' complaints in the irradiated regions. The nasal cavity mucosa was often found to be atrophic, and nasal septa and turbinates had focal hemorrhages, erosions and leukoplakia. These symptoms were collectively referred to in our records as a hemorrhagic/dystrophic syndrome.

The gynecological interviews revealed irregular menstruation to be a common occurrence. The heart specialists' findings included EKG-detectable myocardiodystrophy, arterial hypotony (hypotension) and blood-vessel brittleness. Also detected were delayed filling of the capillaries of the nail bed and aneurysmal dilatation of the popliteal arterial capillaries against a turbid background. Table 8 shows clearly a significant positive association of radiation exposure with these symptoms.

Table 8. Percentage of the Village Community with Vegetovascular Disorders in the Contaminated and Uncontaminated Settlements, 1957-1958.

	Contaminated		Uncontaminated
Symptom	Kainar	Sarzhal	Shchadra
Asthenia	67.0	51.0	13.9
Arterial hypotony	45.8	48.8	9.8
Vascular permeability	69.3-80.0	46.0-70.0	15.0-37.0
Changes in phalangeal capillaries	95.2	97.8	69.7
Elevated protrombin time	90.0	49.1	21.1
Positive blood fluorescence	83.2	51.1	30.0

A symptom complex, previously unknown to this region and apparently secondary to intense and chronic radiation exposure, was identified. The salient features of what has since been called the Kainar Syndrome were asthenia combined with vascular hypotony; a set of hematological disorders comprising anemia, leukopenia, lymphopenia, and thrombocytopenia as well as lymphocytosis and reticulocytosis; and pronounced pathology of the skin, hair and nails. It is to be noted that a 46 to 56% incidence of the symptoms was recorded for the Abai and Beskaragai district inhabitants who would have received 1.60 to 2.00 Gy radiation doses. These symptoms appeared to have a remarkable stability. There was no perceptible decrease in their incidence within a year after their detection, as Table 9 clearly shows.

In addition to asthenic syndrome and vegetovascular dystony, several CNS processes were negatively affected. A large number of the subjects displayed a higher than normal threshold of sensitivity of olfactory and gustatory analyzers, but the performance of the vestibular analyzer was low even though the auditory threshold was high.

Table 9. Case-control comparison of the Kainar Syndrome incidence a year after the diagnosis.

	1958		1959	
Locale	Number of subjects	Percent of cases	Number of subjects	Percent of cases
Kainar	456	46.7	366	54.9
Sarzhal	377	53.6	358	57.4
Karaul	542	38.4		
Dolon I			369	29.9
Dolon II			108	6.5
Shchadra			414	14.9
Barshataz	486	26.3		
Ulu Tau	572	8.6		

The above results of clinical investigations were disputed by the STS authorities and the Ministry of Defense officials. Insisting on the 0.10 Gy dose determined by them for Kainar, they argued that the clinically detectable level of morbidity was due rather to vitamin C and nicotinic acid deficiency and to such common local illnesses as brucellosis and tuberculosis. However, when the archives were opened in 1991, it became clear that the Kainarians' original dose was 2.00 Gy. As to the vitamin deficiency, which is indeed typical of the Kazakh diet, it was found to be the same for the case and control populations.

Blood pressure was also examined during the 1958-1959 expeditions. Decreased systolic pressure was observed in 63.2% of the exposed populations, and the diastolic pressure was found decreased in 48.3%, compared to 22.4 and 22.6%, respectively, in controls. Radiation exposure could thus be implicated in a twofold excess of arterial hypotony around the STS. The level of hypertensive disease was found, however, to be much lower in a reexamination of these groups conducted by No. 4 Specialized Dispensary in 1962. For the 29- to 59-year-old group, the percentage of lowered systolic pressure cases dropped to 17.5%; and an even greater decline, to 9.5%, was found in lowered diastolic pressure. The controls were reported to follow the same trend, but the researchers were unable to support that conclusion with statistical data of adequate significance.

Table 10. Blood Pressure Levels Observed at Sarzhal and Kainar in 1958.

		Systolic pressure (mm Hg), by percentage of surveyed population		
Village/town	N	<101	102-139	>140
Kainar	284	48.5	48.7	2.9
Sarzhal	279	46.1	51.8	2.4
Shchadra*	323	18.4	75.8	5.6

* A town in Pavlodar Province, used as control.

Our subsequent examinations, conducted in 1964 and 1966, confirmed the original findings. Indeed, the arterial pressure had assumed a strong tendency toward increasing in the contaminated areas, particularly with women. The 1964 study indicated that a mere 8.5% of the subjects had their systolic pressure decreased; in contrast, the hypertension group had enlarged substantially. In all age groups, the case subjects were found to be far ahead of the controls in regard to hypertension incidence.

In 1976, the percentage of 2.00 Gy cases with systolic hypertension was 38.6 and 48.5%, respectively, for quadragenarian and quinquagenarian age groups against the corresponding values of 22.6 and 30.1% for controls. Moreover, it seems that radiation exposure history was bringing down the lower age limit for hypertension: among the exposed subjects aged 30-39, one-fourth was suffering from the disease, whereas the corresponding percentage for the controls was only 13%. Arterial hypertension was found to be typically combined with early stages of sclerosis, as judged by the condition of the blood vessels, and disturbed lipid metabolism. In fact, the state was none other than preclinical atherosclerosis.

Kinesiologic examinations of the exposed subjects suggested the presence of changes in the nervous and cardiovascular systems that were occurring some 10 to 15 years ahead of the due biological time, leading as they did to premature aging.

1.11 The Interdepartmental Commission's Study (1989)

The apparent reason for setting up the Commisssion was to address the local public's concern. Established by the Union's Ministry of Health and utilizing specialists from Moscow, Almaty, and Semipalatinsk, the Commission conducted a four-week selected study of the state of public health in Sarzhal, Kainar, and (noncontaminated) Kokpekty and also looked at some of the notes from the STS and No. 4 Dispensary.

Following are the findings of the Commission:

- During 1949-1963, 266 nuclear weapons tests were conducted on the ground and in the atmosphere.
- Through October 1989, at least 300 nuclear devices were tested under the ground, with every third test accompanied by accidental egress of gases or nuclear fission products.
- Until 1986, the underground testing depth was less than 500 m; no radiation monitoring other than by the STS was instituted.
- The 1949 test caused extensive contamination in both Kazakhstan and Russia. The outdoors radiation dose was 2.00 Gy/h and within the first 24 hours of the event the dose received by population was about 1.00 Gy, giving a conservative monthly dose of 1.60-2.00 Gy. The then accepted radiation safety limit was 0.50 Gy/year, which has since been reduced to 0.35 Gy for 70 years. The magnitude of the internal radiation dosage can only be estimated by retrospective calculation. Body organ-allocated doses would include 1.30 Gy for thyroid gland and 0.90-1.00 Gy for gastrointestinal tract and skeleton. For children, these doses should be multiplied by a factor of 20.
- The ionizing radiation doses received in consequence of the thermonuclear test on 12 August 1953 were substantial even taking into account the partial evacuation, which lasted nine days. After nine days the radiation level was measured to be 60 μR/h, representing a threefold excess over the background.
- The use made of nuclear explosion power for "peaceful purposes" at the river Chagan in January 1956 led to contaminating an area of considerable expanse. The fallout gave rise to a 50,000 μR/h level in the city of Semipalatinsk and the adjoining rural area. Meat and dairy deliveries from the affected localities contained various radionuclides at concentrations exceeding the safety limits by hundreds of times; the estimated adult consumer dose would be 0.60 Gy for the thyroid gland and some 0.15 Gy for bone tissue. The other known upsurges of environmental radiation level that could be implicated to STS activities include a rise to 350-500 μR/h in Semipalatinsk city on 7 May 1987 and another one to 45 μR/h in the same place on 18 October 1987. A peak of 3200 μR/h in the

village of Chagan was recorded on 18 February 1989, together with a jump to 170 μR/h in the village of Bolshaya Vladimirovka.

- C-14, though not an abundant fission product, does have a very long halflife and is biologically very important. Yet it was never made an object of radiation monitoring, despite its well-known involvement in biological cycles and potentially strong adverse effect on human health.
- A selected radiological check conducted by the Commission on June 5, 1989, revealed the presence of α particles in the soils of Sarzhal pastures. However, neither STS nor Dispensary records mention plutonium isotope contamination.
- The Commission noted that internal directives had warned the medical staff against indicating the true cause of death in cases of cancer, leukemia, and other radiation-related diseases.
- A ruling was made to classify the results of the investigations conducted by the No. 4 Dispensary and Kazakh Academy of Sciences missions.
- The Kazakh Academy of Sciences Mission identified and described a hitherto unknown set of symptoms observed including asthenia, vascular hypotony, defective hemopoesis (anemia, leukopenia, lymphopenia, thrombocytopenia, and lymphocytosis) and skin and corneum disorders. This disease, that had never before been encountered in the region, came to be referred to as the Kainar Syndrome, from the place where it was first discovered.
- The immune system was found to be below normal range in 50% of patients examined in Sarzhal and Kainar and in 8-10% of the Kokpekty patients.
- The Commission noted evidence of cytogenetic aberrations in the subject region. The populations around the STS and of the city of Semipalatinsk were displaying levels of spontaneous mutations/chromosome breakage which were four to five times higher than the normal rate of two to four percent. Most of the aberrations were of the exposed populations, compared to only one-third of that proportion of the intact population. The number of aberrant cells with chromosomic irregularities was seven times as high, too.
- Malignant tumor mortality in Sarzhal and Kainar was found to show a 40% excess over that in Kokpekty. The cancer mortality curve for the subject area exhibits two peaks reaching twice the average regional cancer incidence value and occurring six to twelve and 21-23 years after the exposures of 1949-1953.
- Nearly half of all the local children (248,000) are at high risk for chronic diseases: 60% of the urban children and 65% of the rural children were found to be in need of restorative treatment. In Semipalatinsk city, the pediatric disease incidence appeared to be three times higher than in the rest of Kazakhstan. Children with individual or familial exposure history were found to account for two-thirds of the observed cases of hypochromic anemia, thrombocytopenia, monocytopenia, and reticulocytosis. Decreased lym-

phocyte count had a frequency that was 1.5 times that observed elsewhere in Kazakhstan.

- Children with exposure history also proved to be twice as susceptible to infectious and contagious diseases, particularly to their chronic varieties, and to tuberculosis. Excess alopecia was even greater, three times the norm.
- The childhood mental retardation rate around the STS was estimated at three times the Republic's average.
- Gynecological pathology leading to pregnancy and puerperal complications was noted in 68% of the subjects, against the 29% Kazakhstan average.
- Compared with 1970, the average longevity had been reduced by two years in Semipalatinsk province.

1.12 Pedatric Issues

Children under 14 account for 31.4% of Semipalatinsk Province's population, numbering 263,300 out of the total 837,900. A recent study [1] found that childhood morbidity around the STS was the highest - by a large margin - in Kazakhstan. Partial data from the report is illustrated in Table 11.

Table 11. Childhood (1 month to 14 years of age) Morbidity Around the STS (per 100,000 children), 1993.

Disease type	Semipalatinsk Province	Kazakhstan
Endocrine and immune system	1119.4	680.1
Blood and blood-producing organs	986.1	1789.2
Respiratory organs	65613.0	48239.2
Psychiatric disorders	457.3	303.5
Neoplasms	65.7	51.7

Comparison between the 1988 and 1992 data reveal an upward trend in Semipalatinsk Province's childhood morbidity. The rate of blood diseases had almost doubled, whereas the endocrine and immune system diseases had increased in frequency by half. Compared with the much less contaminated neighboring Pavlodar Province, the Semipalatinsk region is also high in malignant tumor incidence rates: 137/100,000 versus 97.1/100,000, a ratio of 1.4.([2] The pediatric leukoblast and lymphoblast tumors, too, are more frequent in Semipalatinsk than in Pavlodar and East Kazakhstan Provinces.

Childhood allergic diseases of various organs have a comparatively high incidence in areas adjacent to the STS. Allergic atopical dermatitides exhibit torpid development (i.e., slow and of long duration) and involve the gastrointestinal tract or cause complications such as thyroid gland hyperplasia. Kamasheva et al. [3] have found such children to suffer T-system immune deficiency and im-

munocompetent cell malfunction.

Kuderinov et al. [4] studied 490 children born to permanent residents of highly contaminated areas (Karkaralin district) and found that 39% of these had psychiatric disorders of various kinds. Neuropsychiatric disorder incidence was estimated at 343.5/100,000. Next in frequency was developmental and mental retardation. Quantitative analysis of the cumulative psychiatric pathology data has yielded the following sequence: organic disorders of the brain, 43%; mental retardation, 19%; delayed psychical development, 20%; and Down syndrome, 12%. Concomitant somatic pathologies were found in 65% of the cases.

1.13 Infant Mortality in High Radiation Risk Zones

Temporal and subject analysis of infant mortality for the period from 1953-1956 to 1970 has been done by researchers of the No. 4 Dispensary. They considered the age group from birth to 12 months and started their statistics from the mid-1950s, on the assumption that the formation of the effective equivalent doses of radiation produced by the 1949-1953 tests would by then have been complete. The infant mortality rates were calculated by comparing the total of births to the total of deaths within the 12 month old age group (Table 12).

Table 12. History of Birth and Infant Death Rates in Highly Contaminated Abai, Zhana Semei, and Abralin Districts (population sample = 10,850).

	Reference year	**Effective equivalent dose action time**			
	1948	**1954-1955**	**1956-1957**	**1958-1962**	**1965-1967**
Number of births per 1,000 population	53.5±2.2	56.5±2.5	46.9±2.5	47.1±1.4	47.9±1.2
Number of infant deaths per 1,000 births	48.2±4.9	87.6±12.3 69.0±8.1	67.4±7.2	56.5±4.3	

Table 13. History of Birth and Infant Death Rates in Highly Contaminated (after 1949 test) Beskaragai District* (population sample = 12,847).

	Reference year	**Effective equivalent dose action time**			
Births/Deaths	**1948**	**1950-1951**	**1952-1953**	**1954-1958**	**1961-1963**
Number of births per 1,000 population	31.3±1.5	37.0±3.1	38.8±1.4	36.5±1.0	25.2±0.9
Number of infant deaths per 1,000 births	32.6±1.2	84.5±13.6	58.2±7.1	57.4±6.2	49.1±5.3

* Predominantly inhabited by comparatively less quickly growing Russian population.

In Beskaragai, an area populated predeominantly by ethnic Russians, who have a low birth rate compared with the Kazakhs, the 1948 birth rate level was 31.3 ±1.5. But in spite of this, the mortality rate increased 2.5 times, in the year of maximum radiation exposure.

As can be seen in Tables 12 and 13, the maturation of the effective equivalent dose coincided in time with an increase of the infant mortality rate in the contaminated area by 1.8 times for the Abai, Abralin and Zhana-Semei districts, and in Beskaragai by 2.5 times. The last items in both tables indicate a downward trend in infant mortality rates as the effective equivalent dose decreased.

These tables demonstrate that, despite the ethnic differences, the trend in infant mortality for this district is similar. This may be taken as evidence for the causal relationship of this phenomenon with nuclear radiation exposure.

It is also clear from the above two tables that infant mortality peaked 1-2 years after the 1949 (Beskaragai) and 1954 (Abai & Zhana Semei) events. Not shown in the tables are the data for the 1970s, when nearly three decades after the exposure the infant mortality rate decreased to 42/1,000, a rough approximate of the value it had in the reference year. However, this was followed in the early 1980s by a jump to 63/1,000. This upward trend continued through most of the decade, but reversed in the next, with the rate reaching 48/1,000 in 1992.

The infant mortality rate in the control group in the Kokpekty district in the period of observation from 1948 to 1970 remained fairly constant, averaging 35-37 cases per 1,000 live births. By the late 1980s, it had dropped to 30.1 per 1,000 live births.

As elsewhere in Kazakhstan, the Kazakh birth rates are high in Semipalatinsk Province (63%), compared with the Russian (25%) and German (5%) communities. Yet, because of a high infant mortality, which exceeded the regional average by 30%, there was no growth of the juvenile population in Abai and Beskaragai over the decade ending in 1973 (Tables 14 and 15). The main causes of infant mortality are shown in Table 16.

Table 14. The History of Infant Mortality in Semipalatinsk Province, 1956-1991.

Year	Number of infant deaths per 1,000 births
1956	82.6
1961	47.6
1966	29.7
1971	30.4
1976	33.4
1981	38.1
1986	30.1
1988	33.9
1989	34.0
1990	28.6
1991	27.8

Table 15. Comparison of Infant Mortality Rates in Semipalatinsk Province, Republic of Kazakhstan, and Russia, 1975-1991 (deaths per 1,000 births).

	1975	1980	1985	1986	1990	1991
Semipalatinsk Province	32.4	35.7	30.5	30.5	28.6	27.8
Republic of Kazakhstan	38.8	32.7	30.1	29.0		
Russia						17.8

Table 16. Main Causes of Infant Mortality in Semipalatinsk Province, 1980 and 1987-1988 (per 10,000 births).

Most Frequent Cause	1980	1987	1988
Respiratory organ ailments	181	110	147
Infectious & parasitical diseases	85	31	33.9
Organic defects and anomalies	21.6	24.2	19.4
Malignant tumors & psychosis	0.5	1.0	1.0

In addition to a raised level of general and infant mortality, the STS activities brought about changes in the causes of mortality. Thus endogenous and exogenous infections proved fatal to 68.1% of infants in the contaminated as compared with 51.8% in noncontaminated areas. The mortality rate of the leading infectious disease, pneumonia, was even more skewed, approximately double that of the Republic and the USSR. The death toll in the contaminated areas reached 100, which corresponded to 14.3 per 1,000 infant deaths.

It can thus be concluded that the STS tests are causally related to a twofold rise (on the average) in infant mortality for both the exposed populations and the inhabitants of Semipalatinsk province in general.

1.14 Organic Defects of Development

Infant mortality data for the contaminated areas of Semipalatinsk province indicated a proportionate growth of organic defects of development (ODD). Every fifth ODD case ended in infantile death, while the rest of the cases usually rendered the survivors disabled for life and contributed to adolescent mortality. Against 5.5% for the non-contaminated areas, ODD accounted for 19% of all infant deaths in the contaminated areas. About half of the Semipalatinsk Pediatrical Surgery Hospital's ODD patients originated from Abai, Abralin, and the town of Kurchatov [5]. Four out of five patients from Abai were diagnosed for cryptorchidism.

The ODD incidence on record for rural areas of the pre-STS time was 1.9 to 2.4%. A documented rise to 6 per 1,000 births occurred in Abai, Zhana Semei, and Beskaragai some 5-8 years after the major tests. Contamination-free Kokpekty witnessed an upturn of 4%.

The next rise in ODD incidence was recorded in 1962, i.e., a decade after the tests were commenced. However, this does not compare with an unprecedented threefold rise in ODD-related infant mortality and a tenfold rise in ODD incidence (giving 19 per 1,000 births per year) that occurred around the STS in 1985-1988. In contrast, the incidence in Kokpekty remained constant, averaging 5.0-5.1% annually, with the corresponding rate being consequently four times as low.

During the 1960s, the ODD incidence gradually decreased from 14% in 1965 to 9-10% in 1970. This trend was interrupted in 1976 when the ODD rate curve began to climb again, reaching the highest point (thus far) of 15% in 1981. The descent that was resumed soon afterwards has been continuing, with 13% in 1987 and 11% in 1993. Interestingly, the climb of the ODD rate curve for the noncontaminated areas that began at about the same time has not yet slowed, as evidenced by the highest ever 8% in 1989 and 1993, which is a 2% increase compared to rates recorded in 1970 and 1976.

Besides the alternations in its rate, the ODD incidence displays remarkable nonuniformity in spread over the contaminated region. Thus, in Kainar, a village of 2,000 population, there were 25 ODD cases over the last ten years. The district of Zhana Semei had an incidence of 48/1,000 in 1990, whereas the townships of Znamenka and Sotzializm each recorded as many as 70 ODD cases per 1,000 births in the same year. Evaluating the ODD frequency for Semipalatinsk province as a whole, one cannot ignore the fact that in 1988, for instance, the frequency was exactly 25% higher than in the rest of Kazakhstan and represented 2.5 times the average recorded in the provinces of northern Kazakhstan.

The structural pathology of ODD shows little variation between the contaminated and control areas. In both areas, the leading pathologies are microcephalia, developmental defects of the facial cranium, and disabilities relating to the musculoskeletal system, such as short arms and polydactylia. The incidences of these anomalies do vary between the contaminated and noncontaminated locales, however, in that microcephalia, facial cranium defects and Down syndrome have increased in incidence over the observation period to reach their present levels in the contaminated areas; these rates are nearly twice as high as in the control areas.

Because of the sparsity of relevant statistical data, it would not be possible to present a coherent picture of other developmental defects. However, the data given in Table 17 may shed some light on the history of ODD incidence in Semipalatinsk province:

Table 17. ODD incidence in Semipalatinsk province.

	1986	**1987**	**1988**
Number of outpatients with organic heart defects	534	530	836
Number of babies born with organic disabilities	132	156	171
Percentage of anemic pregnant women	12.3%	19.0%	21.0%

1.15 Malignant Neoplasms

Analysis of excessive tumor mortality levels among the exposed populations suggests an inverse dependence between malignant neoplasm risk and the distance to the STS. Thus, the relative risk index (on a 10,000 cases per year basis) was found to be 1.32 for 15,000 inhabitants of six villages located at a distance of 100 km from the STS, whereas for twice that distance - in the case of 20,000 inhabitants of eight villages - the risk index was one-third less in magnitude, with a value of 1.04.

Early data on malignant tumor (MT) deaths in Semipalatinsk province are sparse, especially for the initial decade of STS history. Medical statistics was at a rudimentary stage at that time, and in any event, diagnosing leukemia and malignant tumors as such was prohibited insofar as these related to radiation exposure.

Still, whatever data there are provided enough information to enable one to assess the effects of STS activities over time in the regional and national (Kazakhstan) picture. In 1947-1949, the cancer mortality level in the city of Semipalatinsk was 1.5 to 2 times lower than in Pavlodar and Petropavlovsk, the capitals of the two neighboring provinces to the North. This was possibly due to the fact that the population there was 70% Russian, whereas Russian nationals accounted for only 40-45% of the Semipalatinsk population. Fifteen years later, the ratio of cancer mortality rates was reversed, with the incidence in Semipalatinsk peaking in 1957.

MT incidence statistics were first gathered for Semipalatinsk Province in 1961, when it was 125.5/100,000, more than 35.5% over that year's level for Kazakhstan of 92.6/100,000 (Table 18). This steadily increasing trend in the overall national increase of MT incidence continued throughout the decade: in 1970, the provincial rate was 171.1/100,000, 11.2% higher than elsewhere in Kazakhstan. In 1991, the MT incidence in Semipalatinsk province was 199/100,000, having grown since 1961 by 63%. Around the STS, the rate was the highest - 186/100,00 in 1970, exceeding the Republic's level by 17%. See Table 19 for comparison.

Table 18. History of MT Incidence (per 100,000 persons) in Semipalatinsk Province, Aktyubinsk Province, and the Republic of Kazakhstan.

Year	Semipalatinsk Province	Aktyubinsk Province*	Republic of Kazakhstan
1960-1961	125.5	108.9	92.6
1970	171.7	160.9	156.3
1979	156.0		
1980	157.0		
1985	179.0		
1988	188.9	165.6	181.1
1991	199.0		190.0
1992			186.1

* Aktyubinsk and Semipalatinsk Provinces are similar in climate, geography, ethnic composition, and demography. Aktyubinsk Province is in western Kazakhstan and was not contaminated by fallout.

Table 19. MT Incidence in the Republics of the Former USSR in 1980 and 1989.

	Incidence rates			Standardized rates		
Republic	**1980**	**1989**	**Increase %**	**1980**	**1989**	**Increase %**
USSR total	205.2	252.6	22.9	260.5	287.1	10.0
Russia	231.3	263.3	14.0	281.1	302.1	7.5
Ukraine	238.6	296.7	24.3	259.9	302.1	16.1
Belorussia	190.4	263.1	38.4	271.6	278.6	2.7
Uzbekistan	73.3	80.3	9.3	154.2	176.7	15.6
Kazakhstan	163.6	182.4	11.6	287.6	306.6	6.8
Kyrgyzstan	115.1	122.1	6.0	214.0	230.2	7.4
Azerbaijan	94.6	130.1	37.9	187.7	240.7	8.2
Armenia	125.2	158.3	26.7	216.7	241.3	11.1
Turkmenistan	106.7	89.1	-	240.2	206.1	-
Estonia, (sample Baltic state)	201.4	325.1	19.0	292.8	340.0	16.1

The above data compare favorably with those obtained by subsequent researchers. Thus, the Tsyb Commission's graphs of the provincial versus the Union's rates for 1970 and 1988 established the ratio for Semipalatinsk of 1.2 and 1.3, respectively. The incidence ratio for females was found to be 1.7. To get these ratios in the right perspective, one needs to recall that it should be unusal for a Southern race to lead in cancer incidence over Northerners. (However, in Turkmenistan, Uzbekistan, Kyrgyzstan, and Azerbaijan the incidence of cancer was approximately 1.5-2.0 times lower that in the Baltic republics and Ukraine, probably due to the different levels and quality of medical service.)

The temporal curve describing the MT incidence in Semipalatinsk province has a distinctly wave-like shape. The first broad peak of the 1960s is followed by a downward slope extending to the late 1970s when a new rise occurs that continues to the present.

The excess mortality rate, with respect to all Kazakhstan, of 35% in the 1960s and 14.4% in the 1970s means that if the cancer morbidity rate for the province had been at the same level as that for all Kazakhstan, then there have been less than 170 excess MT deaths per year in the 1960s and 110 in the 1970s. For the decade of the 1960s this would mean approximately 1,400 excess cancer deaths and for the 1970s about 900, leading over the period of two decades to 2,300; in the context of the Semipalatinsk region, this might represent the radiation-induced cancer casualty.

The following is the geographical distribution of MT rates (per 100,000 population) in Semipalatinsk Province, the districts thereof and the Republic of Kazakhstan in 1988:

Semipalatinsk city	221.6
Abai district	227.9
Beskaragai district	170.6
Zhana Semei district	218.0
Kazakhstan Republic	161.0-181.0
Semipalatinsk Province (1987)	188.9
District of Chubar Tau (contamination-free)	118.7

The proposed positive association between excess tumor mortality and radiation exposure can be demonstrated in the instance of the village of Kainar. The village's population was 1,600 in 1960 and, due to natural growth, 2,540 in 1988. Over a quarter century since 1965 (when the statistical record was started), the community lost 214 members to cancer; i.e., the MT rate was 449/100,000. This represents almost 2.5 times the corresponding index for Semipalatinsk province (189) or the Republic (181). Over the same period of time, 14 Kainarians died of leukemia, which represents a 28/100,000 rate - three to four times in excess of the rates for the entire Soviet Union (9.2) and Kazakhstan (6.2).

The No. 4 Dispensary, which was the medical arm of the Ministry of Medium Machine Building, (the term used for the ministry responsible for building nuclear weapons) has over the years gathered an extensive database on the carcinogenic effect of the STS tests on the population. The file begins at the time (1954) by which 70 to 80% of the effective equivalent dose had been in place around the STS.

The study of MT incidence went on for 35 years and enrolled 190,700 subjects from the radiation contaminated areas and 62,100 inhabitants of Kokpekty who were considered as controls, as this was the population that had received the lowest (100 mGy) dose of all around the STS. The MT incidence per 100,000 was determined to be 159.5 for men and 96.5 for women in the contaminated areas; the corresponding figures for controls were 119.6 and 72.8, respectively. The indices are the averages for a 30-year period. The 33.4% excess for the exposed group is evident.

An ongoing medical examination program was started in the early 1950s with 1,473 subjects from six villages of Abai and Beskaragai districts, where original radiation doses of 1.20 to 2.00 Gray prevailed. The MT rates obtained in a case-control study based on these examinations are presented in Table 20 as a time series scaled on the 30-year history of the effective equivalent dose beginning in 1956, when regular medical checks and mortality accounting practices were fully established.

Table 20. Dynamics of MT Mortality Rates after 1954 (time of deposition of 70-80% of the effective equivalent dose).

Year	1,473 exposed subjects			750 control subjects		
	Years after 1954	**Mortality rate (per 100,000)**	**Ratio to baseline**	**Mortality rate (per 100,000)**	**Ratio to baseline**	**Odds ratio**
1956	2	49	1.00	41	1.00	1.25
1960	6	130	2.65	64	1.56	2.00
1962	8	135	2.75	70	1.70	1.92
1965	11	150	3.06	90	2.19	1.60
1967	13	149	3.04	85	2.07	1.75
1970	16	130	2.65	125	3.05	1.04
1974	20	117	2.38	105	2.56	1.11
1978	24	137	2.78	109	2.66	1.26
1984	30	143	2.92	109	2.66	1.31

Baseline year = 1949

It can be seen that the initial difference in mortality rates between the exposed and control groups was 20%. But as the time interval between the start of the STS activity and recording of mortality rates lengthened, the excess of the mortality rates in the exposed population began to be several times the baseline value measured in 1956. An upturn in MT mortality was taking place in the control group too, but the size of the increment was generally 1.5 times smaller.

The higher cancer mortality rates are seen to occur 6 to 13 years after the formation of 70-80% of the effective equivalent dose, which took place within 5 years of the first test. Over the initial decade of observation, the MT level trebled. The rates observed during the next decade are slightly lower, but 30 years after the exposure, the mortality level began to rise again and continues rising to the present.

On the whole, mortality was rising 1.4 times faster for exposed subjects than it did for controls during 27 years of observation, 0.033% against 0.023%, and its growth was 1.3 times as fast during the succeeding decade. Males in the exposed group had the highest mortality rate of all.

Table 21. MT mortality by sex in the study areas and in Semipalatinsk Province, 1995.

Sex	Population groups	Number of deaths	Mortality rate (per 1,000,000)	Odds ratio
Males				
	exposed subjects	277	1595(96)	
	control subjects	570	1196(50)	1.33
	Semipalatinsk Pr.	4022	1322(21)	1.21

Table 21. (Continued)

Sex	Population groups	Number of deaths	Mortality rate (per 1,000,000)	Odds ratio
Females				
	exposed subjects	186	987(72)	
	control subjects	388	728(37)	1.35
	Semipalatinsk Pr.	2584	786(15)	1.25

Radiation carcinogenesis has brought about a shift of the mortality age towards an earlier time of life (Table 22). The average age of cancer victims among the exposed subjects is 60±0.6 years, whereas among the controls it is 62.6±0.6 years. The corresponding age variation for esophageal cancer is 4 years and for liver cancer 4.3 years.

Table 22. MT mortality by age for exposed and control subjects, 1995.

Age groups	Exposed subjects	Control subjects	Odds ratio
Under 19	61	41	1.49
20-39	232	190	1.22
40-59	2768	1879	1.47
over 59	7150	5789	1.24

Because of generally low mortality for the ages under 40 and the correspondingly large uncertainty in calculated age-related rates, comparison may here prove difficult. The elevated mortality rates for quadragenarian and sexagenerian exposed subjects, on the other hand, lies within a sufficiently narrow confidence interval ($p = 0.001$), and it appears to apply to both sexes (Table 23).

Table 23. MT Mortality Rate by Sex and Age for Exposed and Control Subjects, 1995 (deaths per 1,000,000/yr).

	Exposed subjects			Control subjects		
Sex	Age deaths	Number of rate	Mortality deaths	Number of rate	Mortality ratio	Odds groups
Male						
	40-59	98	3960 ± 410	166	2463 ± 191	1.61
	over 60	165	10551 ± 817	327	8576 ± 475	1.23
Female						
	40 - 59	56	1867 ± 249	129	1440 ± 126	1.30
	over 60	116	4908 ± 454	240	4028 ± 259	1.22

During the observation period, changes in the pattern of mortality were taking place around the STS. The percentage of MT deaths increased to 18.1% in the contaminated areas and only to 12.2% in the relatively unexposed areas.

In both exposed (7,000 subjects) and control (12,000 subjects) groups, cancers of the digestive organs appear to be the most frequent. The increase in gastrointestinal and liver cancer incidence took place about 10-15 years after the 1949-1953 contamination events.

Reliable statistical data show that the yearly gastrointestinal cancer mortality rates doubled in the early 1960s, around the tenth through twelfth year after beginning of the nuclear tests. All age groups appear to have been affected, but the highest degree of confidence was obtained for subjects over 40 years.

Besides the prevalence of stomach cancer among the gastrointestinal cancers in other geographic localities, Kazakhstan, and especially Semipalatinsk province, were found to have a high incidence of esophageal cancer, four to five times that of the level in the entire Soviet Union. Despite such a high level of morbidity from esophageal cancer in the entire republic of Kazakhstan, in Semipalatinsk province the mortality from esophageal cancer measured 63 to 73% higher as compared to the control areas (Table 24).

Table 24. Gastrointestinal Cancer Mortality Rates for Study Groups During 1949-76 and 1977-1985 and for Semipalatinsk Province (deaths per 1,000,000/yr).

Cancer site	Population group	Years after 1949	No. of deaths	Mortality rate	Odds ratio
Esophagus					
	Exposed subjects	1-27	171	472 ± 36	1.78
		28-36	100	491 ± 31	2.44
	Controls	1-27	267	265 ± 16	
		28-36	103	201 ± 13	
	Semipalatinsk Province		2023	320 ± 7	
Stomach					
	Exposed subjects	1-27	128	353 ± 31	1.23
		28-36	72	296 ± 26	1.18
	Controls	1-27	289	286 ± 17	
		28-36	114	281 ± 13	
	Semipalatinsk Province		1714	271 ± 7	1.21

With Hiroshima and Nagasaki victims, leukemia incidence began rising three to eight years after the events and peaked within five-seven years. In the present case, there were two upsurges in lymphoblastosis (leukemia, lymphoreticulosarcoma, Hodgkin's disease) mortality. The first, five years in duration, began six years after the exposures began; the second, spanning some 13 years, followed three years later (i.e. 14-27 years after exposure). Table 25 summarizes the death statistics on leukemia, lymphoreticulosarcoma and Hodgkin's disease for 7,000 case subjects and 12,000 controls, contrasting the data to the contemporaneous lymphoblastosis mortality level in the Province.

Table 25. Lymphoblastosis Mortality in the Study Areas and Semipalatinsk Province (deaths per 1,000,000/yr).

Sex	Population group	Years after 1949	Number of deaths	Mortality rate	Odds ratio
Male					
	Exposed	1-27	14	81 ± 22	2.79*
		10-27	12	95 ± 26	
		28-36	7	65 ± 18	3.09*
	Controls	1-27	14	29 ± 8	
		28-36	8	21 ± 5	
	Semipalatinsk Province	10-27	161	53 ± 4	
		28-36	152	48 ± 3	2.28*
Female					
	Exposed	1-27	5	26 ± 12	2.89*
		10-27	3	20 ± 12	
		28-36	3	20 ± 12	2.50*
	Controls	1-27	5	9 ± 4	
		28-36	4	8 ± 3	
	Semipalatinsk Province	10-27	91	28 ± 3	
Both sexes					
	Exposed	1-27	19	52 ± 12	2.74*
		10-27	16	56 ± 14	
		28-36	10	44 ± 12	
	Controls	1-27	19	19 ± 4	
	Semipalatinsk Province	10-27	252	40 ± 3	

* Confidence level p = 0.01

It can be seen that the lymphoblastosis incidence in the exposed vs. entire province group, 10-27 years after the first test in 1949, is 40% higher for all ex-

posed subjects and is 79% higher with exposed male subjects. When analyzed by age, the lymphoblastosis mortality was found to be elevated for exposed subjects aged 20-59. For those younger and older, the variation between the exposed and control groups appeared to be insignificant.

Separate files on leukemia, sarcomatoses, and lymphogranulomatoses were started for rural areas only eight years before the end of the observation period, and so the data given in Table 26 are therefore presented from only the regional perspective. Adequate confidence levels could only be obtained for leukemia. No significant variations in lymphogranulomatosis mortality were observed. The average age of leukemia victims was 40.7 ± 0.6 years for case subjects and 43.0 ± 0.7 years for controls.

Table 26. Lymphohemoblastosis Mortality in Exposed and Control Areas by Disease Variety (deaths per 1,000,000/yr).

	Case subjects		Control subjects		
Disease variety	**Number of deaths**	**Mortality Rate**	**Number of deaths**	**Mortality Rate**	**Odds ratio**
Leukemia	12	33 ±10	12	12 ± 3	2.75*
Lymphosarcomatosis and reticulosarcomatosis	5	14 ± 3	3	3 ± 3	
Lymphogranulomatosis	2	6 ± 3	4	4 ± 3	

*p = 0.01

A substantial addition to the information provided by Professor Tsyb's Commission and the No. 4 Dispensary on the malignant neoplasm incidence in Semipalatinsk Province is contained in the files of the Statistical Department of the Kazak Ministry of Health. The record for 1980-1990 is abstracted below.

The caseload of MT patients expanded substantially in Semipalatinsk province over the past decade (Table 27). The incidence rates of 169.5/100,000 and 204.0/100,000 for the decade's initial and final years give a 20.4% increase, which on a weighted basis corresponds to an increase of 13.1% from 204.2 to 230.9 (p = 0.01) respectively.

Table 27. MT Incidence by Sex in Semipalatinsk Province in 1980 and 1990 (per 100,000).

	Specific Indices						Weighted Means					
	1980			1990			1980			1990		
Site	**Both**	**M**	**F**	**Both**	**M**	**F**	**Both**	**M**	**F**	**Both**	**M**	**F**
All Tumors	169.5	174.5	164.4	204.0	218.0	190.5	204.2	262.7	168.7	230.9	312.3	182.0
Lip	4.2	7.4	1.5	3.1	5.1	1.2	5.1	0.5	1.3	3.5	6.9	1.0
Oropharynx	2.4	2.8	2.3	4.5	7.5	1.5	2.7	2.9	2.4	5.8	9.8	1.4
Esophagus	31.6	33.0	30.4	20.8	23.9	17.9	38.9	50.0	32.1	22.6	33.7	15.0
Stomach	28.5	34.7	22.3	29.0	36.6	21.9	33.5	47.4	23.3	33.2	54.2	20.2
Colon	2.3	1.8	2.7	5.1	2.6	7.4	2.2	3.3	2.8	5.7	3.4	7.0
Rectum	4.6	2.7	7.0	6.8	6.1	7.5	5.4	3.3	6.9	8.1	9.5	7.3

Table 27. (Continued)

	Specific Indices						Weighted Means					
	1980			1990			1980			1990		
Site	Both	M	F	Both	M	F	Both	M	F	Both	M	F
Liver	3.7	4.7	2.7	7.7	9.8	5.8	4.8	7.3	2.9	9.0	15.5	5.4
Pancreas	2.0	1.8	2.2	6.3	6.8	5.8	2.6	3.0	2.1	7.2	9.5	7.3
Trachea	2.5	4.6	0.5	3.0	5.6	3.5	3.1	6.9	0.6	3.2	7.2	0.3
Lung	22.3	37.4	8.2	35.1	57.5	13.7	27.5	56.2	8.7	41.8	84.9	13.0
Melanoma	0.3	0.5	0.1	1.8	1.0	0.3	0.3	0.8	0.1	2.0	0.7	2.9
Other skin neoplasms	16.5	14.2	18.7	18.8	17.9	19.8	18.4	21.2	16.7	20.9	28.7	17.3
Breast			18.4			14.0			19.6			24.6
Cervix			17.4			11.6			18.3			11.6
Ovary			6.9			7.4			7.7			7.8
Bladder	2.2	3.7	0.7	3.3	6.1	0.7	2.5	5.6	0.8	3.8	9.0	0.6
Thyroid	0.8	0.5	1.0	2.4	0.7	3.9	0.8	0.4	1.0	2.5	0.9	4.0
Lympho-hemopoietic	2.4	2.7	2.1	9.3	11.5	7.2	2.7	3.0	2.1	9.9	14.5	7.4

For males, the incidence rates were markedly higher than females: 174.8 against 164.4 in 1980 and 218.2 against 190.5 in 1990. The incidence percentage change also is 1.3 times higher for males, the corresponding figures being 24.8 and 15.9%.

Site analysis of the incidence data indicates raised levels for all cancers except labial, thoracic, cervical and prostatic tumors. The incidence of thyroid, pancreas, lymphatic and hematologic neoplasms increased threefold. A 1.5 to twofold increase occured in the frequency of tumors of the lung, colon, rectum, oral cavity, oropharynx, liver and breast. An increase also took place in the level of throat, urinary bladder, skin and stomach cancers.

Sex variations in the incidence of some of the cancers were expressed to a remarkable extent. Oral cavity and oropharynx neoplasms doubled in frequency with men, from 2.3/100,000 in 1980 to 7.5/100,000 in 1990, whereas a fall in the corresponding incidence occurred with women. Rectal cancer incidence saw an increase, principally with males. The colon, on the other hand, was the site of far more frequent neoplasms with females. The rise in lymphatic and hematologic neoplasms showed little variation by sex, but thyroid tumor incidence in the female sex jumped to 3.9/100,000 in 1990 from 1.0/100,000 in 1980. There was a comparatively low, but still significant increase in lung cancer with women - from 8.2/100,000 in 1980 to 13.7/100,000 in 1990.

The observed changes in incidence were paralleled with changes in the site distribution (Table 28) and the relative rating of the principal cancers (Table 29). First in importance is a shift in the frequency of lung cancer, from every seventh case in 1980 to every fifth case in 1990. Similar frequency alterations took place for oropharyngeal neoplasms (71 in 1990 compared to 45 in 1980), rectal cancer (38 vs. 30), tracheal neoplasms (71 vs. 76) and most notably for hematologic and lymphatic neoplasms - from 23 in 1980 to 77 in 1990. At the same time, some cancers took a downward trend: esophageal cancer incidence

decreased by four points from its 1980 frequency of 10/100,000, the rate for labial cancer dropped off by more than a third (40 from 67), and the incidence numbers for stomach and cervix cancers became, respectively, 6/100,000 and 19/100,000 compared to 7/100,000 and 34/100,000 respectively in 1980. Sex variation in incidence changes are more marked for lung cancer, which in 1990 accounted for one in every four tumor cases with males, but only for one in every fourteen with females.

Table 28. MT Incidence in Semipalatinsk Province for 1980 and 1990 by Site and Sex (percentages of all cancers).

	Both sexes		Males		Females	
Site	**1980**	**1990**	**1980**	**1990**	**1980**	**1990**
Lip	2.5	1.5	4.2	2.4	0.8	0.6
Oropharynx	1.4	2.2	1.5	3.5	1.3	0.8
Esophagus	17.9	10.2	18.8	10.9	18.5	9.4
Stomach	16.1	14.2	19.4	16.7	12.9	11.5
Colon	1.4	2.5	1.0	1.2	1.6	3.9
Rectum	2.6	3.3	1.5	2.8	3.7	3.9
Liver	2.2	3.8	2.7	4.5	1.6	3.1
Pancreas	1.2	3.2	1.0	3.1	1.3	3.1
Trachea	1.5	1.5	2.6	2.6	0.3	0.2
Lung	13.4	17.2	21.5	26.4	4.9	7.2
Melanoma	0.2	0.9	0.3	0.2	-	1.6
Other skin neoplasms	9.7	9.2	8.1	8.2	11.4	10.4
Breast	5.8	6.0	-	-	11.2	12.6
Cervix	5.3	2.9	-	-	10.6	6.1
Endometrium	1.9	2.0	-	-	3.8	4.2
Ovary	2.1	1.9	-	-	4.2	3.9
Prostate	0.3	0.5	1.7	1.0	-	-
Urinary bladder	1.3	1.6	2.1	2.8	0.4	0.4
Thyroid gland	0.5	1.2	0.3	0.3	0.6	2.1
Lymphohemo-poietic tissue	1.3	4.3	1.5	5.3	1.2	3.8

Table 29. 1980 and 1990 Ratings of Principal Cancers in Semipalatinsk Province by Sex.

1980		1990	
Both sexes			
1. Esophagus	31.6	1. Lung	35.1
2. Stomach	28.5	2. Stomach	29.0
3. Lung	22.3	3. Esophagus	20.8
4. Skin	16.5	4. Skin	20.6
5. Breast	9.5	5. Breast	12.3
6. Cervix uteri	8.9	6. Lymphohemopoietic tissue	9.3
Men			
1. Lung	37.4	1. Lung	57.5
2. Stomach	34.7	2. Stomach	36.5
3. Esophagus	33.0	3. Esophagus	23.7
4. Skin	14.2	4. Skin	17.9
5. Lip	7.4	5. Lymphohemopoietic tissue	11.5
6. Liver	4.7	6. Liver	9.8
Women			
1. Esophagus	30.4	1. Breast	24.0
2. Stomach	22.3	2. Skin	22.8
3. Skin	18.7	3. Stomach	21.9
4. Cervix uteri	12.3	4. Esophagus	17.9
5. Breast	9.3	5. Lung	13.7
6. Rectum	7.0	6. Cervix uteri	11.6

It can be seen in Table 29 that in 1990 the leading cancer in Semipalatinsk Province was lung cancer, which came to the top from the third position it occupied in 1980, having swapped with esophageal cancer. Stomach cancer remained second in frequency; also stable were skin and breast cancers. An important newcomer on the scene was lymphohemopoietic cancers, whereas cervical cancer had left the principal group.

With men, the only change in regard to position occurred for labial cancer, which had been replaced with cancer of the blood and blood-producing organs.

In contrast, none of the items on the women's rating list kept its place; the strides made by breast cancer upward and esophageal cancer downward are impressive. The appearance of lung cancer on the top 6 cancer list for women is significant.

Thus, the malignant tumor incidence has increased considerably in Semipalatinsk province over the past decade, with major rises for tumors of the lung, stomach, skin, breast, pharynx, rectum and colon. A particularly significant increase in frequency has occurred for thyroid, pancreatic, hematologic and lymphatic neoplasms. The relative weights of different cancers have changed and the current leading cancers in Semipalatinsk province are lung cancer with men and breast cancer with women.

1.16 References

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Section 2: Dosimetric Investigations

In order to determine the possible influence of radiation on the health of the population, it is necessary to establish present day external and internal doses; to do this, dosimetry of soils, plants, and foodstuffs was performed.

Our archival research furnished data on external irradiation levels for the environment and population of Sarzhal and Kainar. Internal irradiation doses could then be determined by investigating the migration of nuclides from the original fallout events. Measurements of plutonium and other transuranics elements along with rare earth isotopes produces by fission and neutron activation were done.

An attempt to determine exact individual and group doses in specific villages and towns decades after the irradiation events that were never subjected to dosimetry at the time is by no means a trivial task. The source data, therefore, are such that a generous allowance for error is warranted.

2.1 Methods

Radiometry

Contaminated Area

Using the II-01T dosimeter, the intensity of radiation exposure dose was determined by γ survey of the ground. An integral part of the field sampling was the determination of the radiation diffusion length. Using the α- and β-particle density data, determinations of the soil contamination level were carried out in 5 cm steps.

The MKC-01-P-01 radiometer employed was supplied with a set of sensor attachments. α-particles were detected with the BDKA-01-P detector. Up to ten measurements were made at each point, with exposures for 100 seconds. In order to make β-particle determinations possible against a γ background, β-radiation measurements were taken using the BDKA-01-P detector which is supplied with a γ-ray filter. The β-radiation component was determined as the difference between γ-particle readings taken with the filter on and $\gamma + \beta$ measurement data obtained with the filter off. Each round consisted of 10 runs, with an exposure time of ten seconds for each run.

Based on these measurements, the soil sampling depth ranges were determined as follows: between zero and five cm and between 7 and 12 cm for Sarzhal, 0 to 5 cm for Tailan, and from zero to five and 20 to 25 cm for Kainar. To provide ourselves with a reference scale, similar measurements of α- and β-particle intensity and variation thereof with depth were carried out in the city of Semipalatinsk.

Kokpekty

The basic instrument used to measure α, β, and γ radiations was an MKC-02R-01 radiometer equipped with a set of sensors. However, attempts to obtain a consistent representation of inward migration of radiation at Kokpekty were unsuccessful. This is due to both a high sensitivity of the technique and the probable absence of any substantial contamination over a number of preceding years.

2.2 Sampling

Contaminated Area

Soil. Selection of sampling sites within dwelling areas was based on the dosimetric results obtained. An important criterion was the absence of any apparent signs of previous business activity on the site, such as land cultivation, construction, or dumping. The site was cleared of topsoil and large and sharp stones. Following the dosimetry, samples were taken, with each sample measuring five cm in thickness and weighing, on the average, three kg.

Plants. Two relevant criteria were proximity to soil sampling location and, in the case of hay, to dwellings. Typical sample masses were 1 to 1.5 kg for green grass and 0.5 kg for hay.

Meat, bone, and milk. The products to be sampled were purchased from inhabitants in the amount of six kg per sample.

Water. This was sampled at water sources (bored and covered wells) for people and cattle. The sample volume was 10 liters.

Kokpekty

The village is divided into two geologically distinct parts by a river—an acclivity ascending from the right bank and a valley extending from the left bank. On the right-bank side, there is a communal water-supply facility, whereas the dwellers of the left-bank side get their water from artesian wells. Two samples were taken from the right-bank and four samples from the left-bank sides. The samples were subsequently combined because of low activity readings. Soils were sampled at the depths of 0-5, 5-10, 10-15, and 20-25 cm.

The sites of plant sampling were typically pasture lands for grazing private livestock. Milk and meat samples were collected on a random basis, usually in small quantities. The number of samples of each type studied were:

Soil	Hay	Meat	Milk	Water	Bones
30	6	6	6	6	6

2.3 Specimen Preparation

The soil samples were dried at 60 to 80 °C, cleared of foreign bodies, and screened using a 3.25 mm gauge sieve. Gamma-spectroscopic specimens, each 1.8 to 2.5 kg in mass, were packed in Marinelli tubes. The preparation of the radiochemical specimens, 80 to 100 g each, included ashing treatment at temperatures ranging from 400 to 450 ºC.

The plant specimens were first dried at 40 to 50 ºC for 20 h at ambient humidity and then subjected to a foreign body cleanout. This was followed by a 400–450 ºC ashing stage, performed, as the volume of the ash was reduced, in two steps involving the use of stainless steel and ceramic cuvettes. Thermal treatment was accompanied with continuous grinding and facilitated by addition of small quantities of concentrated nitric acid. The ash obtained was screened using a one mm gauge sieve and placed in plastic Petri dishes. In the study protocol, γ spectrometry preceded radiochemical measurements.

The preparation of the meat and bone specimens involved removal of fat and sinew, dehumidification and ashing. The latter two stages were also involved in the preparation of milk specimens. Premeasurement preparation of meat, bone and milk specimens was similar to that used for plant specimens. The basic steps of water specimen preparation were filtering through 42-micron mesh gauze and condensation.

2.4 Gamma Spectroscopy

Radionuclide determinations were made using two instrumental sets which comprised:

- Germanium-based diffusion-drift K-506-3 and K-63-B detectors supplied with a 100-mm lead protection screen.
- Multichannel amplitude pulse analyzers AII-1024-95-17M.
- EC-1841-11 personal computers.
- Gamma-spectrum treatment software BaltiSpectr 3.02.

The measurements ranged in duration from 3.5 to 5.5 h.

Marinelli tube geometries were used for soil and Petri dish geometries for water, plant, and foodstuff samples. The ranges of the energy-related sensitivities were as follows:

Energy	**Marinelli tubes**	**Petri dishes**
186.1 keV	0.301 ± 0.136 Bq/kg	0.011 ± 0.003 Bq/l
661.662 keV	0.501 ± 0.249 Bq/kg	0.021 ± 0.02 Bq/l
1460.75 keV	20.156 ± 6.047 Bq/kg	1.311 ± 0.641 Bq/l

2.5 Radiochemical Investigations

In the case of soil specimens previously treated at 450 ºC, the samples used in Sr-90 determinations were 80-100 g in mass; the previously condensed water samples weighed 20 to 30 g. The dissolving agent was strong (3N) nitric acid. The associated radioactive elements were separated by coprecipitation (see description below). The daughter Y-90 obtained was precipitated and its amount measured radiometrically.

The radiometric sets employed comprised:

- A β-particle detector complete with CBT-10 counter and a 50-mm wall lead screen.
- A IICO2-4 converter.
- A set of the required electronic and physical equipment.

Measurement time periods were between 1.0 and 1.5 h. The sensitivity threshold for the method employed was 0.05 Bq/kg, with a standard error of 27.7%.

2.6 Radiochemical Analysis

1. Following the ashing procedure as described above, the sample was immersed in 200 ml of aqua fortis which had been boiled for 30 min. Following the addition of 10 ml of stable strontium carrier, the suspension was filtered out, and the insoluble precipitate washed with hot water on the filter screen and discarded.
2. The filtrate was then mixed with 50 ml of saturated ammonium acetate and ten ml of saturated ferrous chloride solution. The adjustment of the pH reading to 5.0 was accomplished using decarbonated ammonia.
3. The solution and its precipitate were boiled for three min and then filtered while still hot.
4. The filtrate was again mixed with saturated ferrous chloride, and then excess amounts of decarbonated ammonia were added to cause iron hydroxide to precipitate.
5. The resultant precipitate was filtered, washed with aqueous ammonia and discarded.
6. Using 3N nitric acid, the filtrate's pH was adjusted to three-four; then three ml of stable yttrium carrier was added, and an yttrium hydroxide precipitate was formed through decarbonated ammonia oversaturation.
7. The yttrium hydroxide precipitate was filtered off using a paper filter and discarded.
8. The filtrate was then treated with saturated ammonia carbonate to produce second-group carbonates which were also filtered.
9. The resultant residue was dissolved in a sufficient amount of 3N nitric acid and the solution slowly evaporated to yield a dry residue.
10. This was turned to fine powder by pounding in 100 ml of acetone, stored overnight, and filtered. The filtrate was washed in acetone, dissolved in sufficient amounts of hot distilled water poured onto the filter, and acidified with one ml aqua fortis.
11. Following the addition of one ml of stable yttrium carrier, the solution was incubated for 14 days until the formation of the daughter Y-90. Precipitating and filtering out of yttrium hydroxide was done with decarbonated ammonia.
12. The last procedure was repeated when yttrium hydroxide was turned into a solution by treatment with 3N acidic acid on the filter, just as in the filtering and aqua ammonia washing steps. The aggregate filtrate was subsequently used for determination of the stable strontium carrier yield (item 14).
13. Activity measurements were performed on the dried sediment of yttrium hydroxide.
14. To make determinations of the stable strontium carrier yield possible, the volume of the aggregate filtrate was amplified

to 100 ml with distilled water. Three aliquots, five ml each, were sampled from the solution obtained, and each placed in a titration flask along with ten ml ammoniate buffer solution (pH 8-10), where ten ml of 0.005N zinc complexing solution plus an indicator mixture were added in adequate amounts to bring out the violet. Following the addition of distilled water of up to 50 ml in volume, the content of each flask was titrated by adding 0.1N EDTA solution until the color changed to blue-green.

15. The chemical yield of the strontium carrier was determined by the formula (2.1)

$$B = 0.088 \frac{V_{edta}}{K_{sr}} \qquad (2.1)$$

where

B is the chemical yield of the strontium carrier;

V_{edta} is the volume of titrated 0.1N EDTA solution, averaged over the three aliquots; and

K_{sr} is the correction factor for titrated solution of stable strontium carrier.

2.7 Nuclide Activity Determinations

Sr-90's activity was calculated by the formula (2.2)
where

$$A = N \frac{K_{yct}}{K_t} B m(V,S) \qquad (2.2)$$

A is the specific (bulk, surface) activity of Sr-90 (Bq/m^3, Bq/m^2);

N is the rate of count for the Y-90 specimen (pulse/min);

K_{yct} is the instrumental factor (Bq x min/pulse);

K_t is the Y-90 decay quotient;

B is the chemical yield of stable strontium carrier;

$m(V,S)$ is the mass/volume/area of untreated samples, in kg/m^3 or m^2.

To allow for an error, A was corrected as follows (2.3):

$$\Delta A = A \left[\frac{\Delta N}{N}\right]^2 + 0.0082 \qquad (2.3)$$

where

ΔN is the measurement error in regard to the rate of count for the yttrium specimen, pulse/min.

2.8 Internal Irradiation Dose Computations

Assumptions governing exposure calculations were as follows:

- The values of Cs-137 and Sr-90 concentrations in foodstuffs (meat, milk) and drinking water are assumed to be constant on an annual basis.
- Intake of contamination is taking place daily throughout the year.
- Dose calculations are for adults under 50.
- Ca protection is neglected, as tests to determine Ca content in the target foodstuffs were not included in the protocol.
- The conventional daily diet includes 0.2 kg of meat, 0.51 of milk and 0.2 kg of broth bones.
- The boiling extraction rate for bone-embedded Sr-90 is 1%.
- Both Cs-137 and Sr-90 are assumed to have uniform distribution over a given organ or tissue.
- For Sr-90, the dose calculation is based on the mass of the skeleton, and for Cs-137, on the mass of the whole body.

The calculation of the internal irradiation dose followed the method given in (2.4) using the following formulas.

NOTE: In calculating the total dose due to consumption of food, no account was taken of the bone tissue damage caused by Sr-90.

(1) $$D_{t_1} = \frac{2 \times 10^{-8} F E_{eff} T_{eff}}{m} \left[t_1 - \frac{1-e^{-\lambda_{eff} t_1}}{\lambda_{eff}} \right] \quad (2.4)$$

where

D_{t_1} =	the equivalent dose received by an organ over the irradiation period;
$F = C \cdot V \cdot f$ =	the rate at which a nuclide gains access to the organ, Bq/24 h;
C =	the nuclide concentration in the organ, Bq per kg/l;
V =	the consumption rate in kg/l per 24 h;
f =	the fraction of nuclides received by a given organ relative to the total amount received by the organism;
m =	the body mass in kg;
t_1 =	the period of irradiation, days;

E_{eff} = the effective energy, MeV/decay; and

T_{eff} = the effective disposal half-period, days.

(2) $$D_{t_2} = \frac{2 \times 10^{-8}\, F E_{eff} T_{eff}}{m \lambda_{eff}} (1\text{-}e^{-\lambda_{eff} t_1})(1\text{-}e^{-\lambda_{eff} t_2}) \quad (2.5)$$

where

D_{t_2} is the equivalent dose received by a given organ after the cessation of irradiation, and

t_2 is the duration, in days, of the intermediate period.

The accumulated dose for periods $t_1 + t_2$ is given by

(3) $$D_{t_1} + D_{t_2} = \frac{2 \times 10^{-8}\, CVFE_{eff} T_{eff}}{m} \left[t_1 - \frac{1\text{-}e^{-\lambda_{eff} t_1}}{\lambda_{eff}} e^{-\lambda_{eff} t_2} \right] \quad (2.6)$$

where

$E_{eff}^{Sr\text{-}90}$ = 1.1 MeV /decay

$T_{eff}^{Sr\text{-}90}$ = 6.551 x 10^3 days

$\lambda_{eff}^{Sr\text{-}90}$ = 1.058 x 10^{-4} $days^{-1}$

Taking the ICRP recommended value of 5 for the Sr-90 damage factor, N, gives

$E_{eff}^{Sr\text{-}90}$ = 5.65 MeV /decay

f, the portion of Sr-90 deposited in the skeleton relative to the total ingested, is equal to 0.09;

m, the mass of the human body, is taken by convention to be 70 kg.

$E_{eff}^{Cs\text{-}137}$ = 0.59 MeV/decay

$T_{eff}^{Cs\text{-}137}$ = 69.6 days

$\lambda_{eff}^{Cs\text{-}137}$ = 9.957 x 10^{-3} $days^{-1}$

f, the proportion of consumed Cs-137 which settles in the body, is equal to 1.00;

m, the mass of the human body, is taken by convention to be 70 kg;

t_1 = 365 days is the intake time;

t_2 = 18,250 days (50 years) is the time following the cessation of intake.

With allowance made for the bone tissue “damage factor”, the integral Sr-90 and Cs-137 internal dose of radiation entering the human body with foodstuffs over a period of 50 years is 4.90 mSv. The value indicated refers to Sarzhal;

determination of the relevant value for Kainar proved to be impossible due to the low nuclide activity exhibited by the samples.

It should be noted specifically that the present work did not address the question of diet, but rather used the dietary data from prior studies, such as [2].

2.9 External Irradiation Dose Computations

The calculation of the relevant doses is based on the mathematical models proposed by Riadov, Gordeev, Stepanov, and others. The protection value employed in the calculations is that for adobe brick, the basic building material for homes near the STS at the time of testing. The doses for the 1953 fallout were adjusted downward to take account of the evacuation. The following equations were used for calculations.

(4) $$t_0 = \frac{R}{\bar{V}} \qquad (2.7)$$

where

t_0 = time of beginning of fallout,

R = distance from the epicenter in km; and

$\bar{V}$ = average wind velocity, km/hr.

(5) $$\Delta t = \frac{0.2\sqrt[3]{q} + 0.32R}{\bar{V}} \qquad (2.8)$$

where

Δt = duration of fallout in hours, and

q = charge yield in tons.

(6) $$t_1 = t_0 + \Delta t \qquad (2.9)$$

where

t_1 = fallout cessation time in hours.

(7) $$D_\Sigma = \frac{D_r}{K_f} + D_f \left[\frac{t_{(OTK)}}{24} + \frac{24 - t_{(OTK)}}{24K_b} \right] \quad (2.10)$$

$$D_f = 5P_f t_1$$

where

D_Σ = total accumulated external γ-radiation dose for the population, rad;

D_t = exposure dose (γ) received during the period of fallout trail formation, rad;

D_f = exposure dose (γ) received from precipitated fallout, rad;

P_f = dose rate from precipitated fallout, rad/hr;

K_f = γ-radiation attenuation factor for the buildings during the fallout trail formation period, assumed to be equal to unity;

K_b = fallout γ-radiation attenuation factor for buildings, assumed to be equal to 13 for adobe brick houses;

t_{OTK} = time in open (i.e. time spent outdoors).

For any interval of time between t_1 and t_2, the dose of the γ radiation emitted by fallout fragments is defined as an integral value of the following function:

$$D = \int_{t_2}^{t_1} P_t \, d_t \quad (2.11)$$

In this case, t_1 spans the time interval starting from the initial descent of the fallout fragments and ending at the termination of the decay period (which is an infinitely long time).

(8) $$D_\infty = 5P_t \, t^{1.2} \, t_f^{0.2} \quad (2.12)$$

where

D_∞ = accumulated γ-radiation dose produced over the entire lifetime of the isotope, in rad;

P_t = the magnitude of the radiation dose as measured at a given point of time t after the explosion, in rad/h;

t = time elapsed after the explosion, in hours; and

t_f = the duration of the time of fallout, in hours.

The final equation is

(9) $$D_{tot} = 5P\left[t_0 - \frac{t_0^{1.2}}{t_1^{0.2}}\right] \tag{2.13}$$

where

D_{tot} = radiation dose over the fallout period, rad;

P = magnitude of the initial _-radiation dose, rad/h;

t_0 = fallout onset time (hours);

t_1 = fallout cessation time (hours).

$$P_f = \frac{D_\infty}{5t_0}$$

where

Pf = dose rate at the moment of fallout, rad/hr;

$D\infty$ = calculated from Equation 8;

$D_f = 5P_f t_1$ = dose of γ radiation from precipitated fallout.

2.10 Calculations

Basic data for the thermonuclear device tested on 12 August 1953 are given in [3]:

q (the total yield of the device) = 470 kT

V (average wind velocity) = 85 km/h

h (height of burst) = 1,000 m

H (maximum altitude of the fallout cloud, over the village of Karaul)
= 17.5 + 1.8 km.

Sarzhal:

R = 110 km

P = 1.19 R/h (25.7h after blast)

P = 0.015 to 0.037 R/h (27 Aug 1953)

Tailan:

R = 100 km

P = 3 R/h (36.6 h after the blast)

P = 0.45 R/h (17 August at 0700 hours)

P = 0.2 R/h (21 August at 1800 hours)

Resettlement to both villages was carried out on 27 August.

Based on the above, the following estimates were obtained:

Sarzhal:

Fallout onset time, from equation 4:

$t_0 = 110 \div 85 = 1.29$ h

Duration of the fallout, from equation 5:

$$\Delta t = \frac{0.2\sqrt[3]{470 \times 10^3} + 0.32 \times 110}{85} = 0.60 \text{ h}$$

Fallout cessation time, from equation 6:

$t_1 = 1.29 + 0.60 = 1.89$ h

Accumulated dose of γ-radiation emitted by fragments from the time of their fallout to the end of the nuclide decay period, from equation 8:

$D_\infty = 5 \times 11.19 \times 25.7^{1.2} \times 1.295^{0.2} = 438$ rad

Magnitude of the dose at the time of fallout:

$$P_{fallout} = \frac{438}{5 \times 1.29} = 67.9 \text{ R/h.}$$

Assuming that the dose produced over the fallout trail formation period is about 10% of that due to γ emissions from settled fission fragments, the resulting accumulated external γ-radiation dose over the time period extending from the fragment settlement to the complete decay of radionuclides thereof is:

$D_\Sigma = 44 + 438 = 482$ rad

The resettlement to Sarzhal and vicinities took place 360 hours after the blast when the dose was 0.015 to 0.037 R/h. Therefore, according to equation 9, the accumulated external γ-radiation dose over the period from resettlement to complete nuclide decay period is

$D_\infty = 5 \times 0.037 \times 360 = 66.6$ rad.

Tailan:

Fallout onset time, from equation 4:

$t_0 = 100 + 85 = 1.18$ h

Fallout duration, from equation 5:

$$\Delta t = \frac{0.2\sqrt[3]{470 \times 10^3} + 0.32 \times 100}{85} = 0.56 \text{ h}$$

Fallout cessation time, from equation 6:

$t_1 = 1.18 + 0.56 = 1.74$ h

Accumulated dose of γ-radiation emitted by fission fragments from the time of their fallout to the end of the nuclide decay period, from equation 8:

$$D\infty = 5 \times 3 \times 36.6^{1.2} \times 1.76^{0.2} = 1697 \text{ rad}$$

Magnitude of the dose at the time of fallout:

$$P_{fallout} = \frac{1{,}697}{5 \times 1.18} = 288 \text{ R/h.}$$

The resulting accumulated external γ-radiation dose over the time period extending from the onset of fragment fallout to the time of complete decay of the radionuclides is:

$$D_{\Sigma} = 169.7 + 1{,}697 = 1{,}867 \text{ rad.}$$

The resettlement of Tailan took place 360 hours after the blast when the dose rate was 0.154 R/h. Therefore, according to equation 9, the accumulated external γ-radiation dose over the period from resettlement to complete nuclide decay is

$$D = 5 \times 0.154 \times 360 = 277 \text{ rad.}$$

Kainar (1951):

The initial conditions [3] were the following:

q (the fission yield of the device) =	20 kT;
V (average wind velocity) =	47.5 km/h;
h (height) =	800 m;
P (dose rate 10 hours after the blast) =	0.27 R/h;
R (distance from the epicenter) =	150 km.

Based on the above data, the computational results are as follows:

Fallout onset time, equation 4:

$$t_0 = 150/47.75 = 3.16 \text{ h}$$

Fallout duration, from equation 5:

$$\Delta t = \frac{0.2\sqrt[3]{2 \times 10^4} + 0.32 \times 150}{47.5} = 1.13 \text{ h}$$

Fallout cessation time, from equation 6:

$$t_1 = 3.16 + 1.13 = 4.29 \text{ h}$$

Accumulated dose of γ-radiation emitted by the fission fragments from the time of their settlement to the end of the nuclide decay period:

$$D_{\infty} = 5 \times 0.27 \times 10^{1.2} \times 3.16^{0.2} = 26.9 \text{ rad}$$

Assuming that the dose produced over the fallout trail formation period is about 10% of that due to γ emissions from the settled fission fragments, the

resulting accumulated external γ-radiation dose over the time period extending from fragment settlement to the time of complete decay of the radionuclides is, per equation 7:

$$D_{\Sigma} = 2.69 + 0.7 \times 26.9 = 21.5 \text{ rad.}$$

2.11 Results

Radiation Contamination of the Soil

Soil pollution in the subject areas is due to global contamination as well as the local contamination produced by the tests. Both natural and anthropogenic nuclides were discovered in the soil samples [4,5]. Averages for α and ß particles and γ rays for measurements conducted in 1994-1995 are given in Table 30.

Table 30. α and ß Particles and γ ray Emitters in Soils of the Subject Areas.

Village/ town	Depth (cm)	α radiation particles per cm² per min	γ radiation per cm² per min	γ + ß radiation per cm² per min	ß radiation particles per cm² per min
Kainar	0	0.13	4.68	9.40	--
	10	0.12	5.96	10.12	--
	15	0.22	6.26	10.57	--
	20	0.80	6.08	10.32	--
Sarzhal	0	0.082	3.24	7.90	4.66
	10	0.508	5.48	6.90	1.42
	20	0.80	3.44	5.34	1.90
Tailan	0	0.085	3.34	8.38	5.04
	10	0.363	4.20	7.72	3.52
	15	0.208	3.88	6.80	2.92
Semipala- tinsk	0	0.12	--	--	--
	5	0.07	--	--	--
	15	0.17	--	--	--
Kokpekty	0	0.45	4.46	7.86	3.40
	10	0.26	5.10	8.03	2.93
	15	0.42	5.73	8.12	2.40
	20	0.46	4.41	7.93	3.52
	25	0.41	5.53	7.76	2.18

The present day averages of soil γ and ß radiation are seen to be identical. Alpha particles were discovered on all four sites. The intensity of α-radiation on the surface was found to six times less than at a depth of 20 cm in Kainar and ten cm in Sarzhal. This is evidence that contamination of Kainar took place earlier than in Sarzhal, assuming similar rates of migration. Subsoil nuclide investigations at Sarzhal and Kainar have provided evidence suggesting that the increase in the observed α activity is due to some pure α-particle emitter rather than to U-235 itself.

Assurance of radiation safety is not possible without a detailed knowledge of transuranic element distribution. Pu-239, a highly toxic element, is produced from U-238 by neutron capture and is also dissipated in the environment as unspent fuel (i.e., that failed to undergo fission) from nuclear explosions. The 1951 test, for example, caused the level of biologically hazardous plutonium to rise to 300 Ci, higher than in 1953 [6].

The most important isotopes of plutonium are Pu-239, Pu-240 and Pu-241. Pu-241 is a pure ß emitter with a half-life of 14.4 years. It produces Am-241 with a half-life of 463 years and 60 kV photon emission detectable by γ spectrometry. Although americium is not a product of nuclear explosions, it is a constant component of the plutonium isotope group, and so can be used to assess the content of Pu-239. Since the spectrographs of the soil samples from all sites exhibited a 60 kV peak, it was reasonable to assume the presence of Am-241.

In the soil samples taken at different depths at Sarzhal the fraction of α particles at depth had an intensity twice as high as at the surface. The ratios for Kainar and Tailan were 1.5:1 and 4.3:1, respectively. No such difference in the intensity of α particle ratios between depth and surface soil layers was found in the city of Semipalatinsk and village of Kokpekty (Table A6 in Appendix).

Nuclear and thermonuclear explosions are accompanied by the massive formation of rare earth radioisotopes in the form of fission fragments and neutron capture products. Along with La-140, Ce-141, Ce-143, Ce-144, Nd-147, Pm-147, which are produced in significant amounts both individually and cumulatively, there are a number of radioisotopes which defy identification by γ spectrometry. This is because of the smallness of the Eu-155 yield, and the presence of such entities resulting from neutron capture by stable rare earth isotopes (Eu-152, Eu-154), which tend to be spectrometrically detectable no earlier than four to six years after the explosion.

Based on the present knowledge of fission patterns, the peaks detected in the spectrographs can be attributed to the following isotopes:

E = 123 keV (Eu-152, Eu-154)

E = 344 keV (Eu-152)

E = 873 keV (Eu-154)

E = 1005 keV (Eu-154)

E = 1,085 keV (Eu-152)

E = 1,112 keV (Eu-152)

E = 1,274 keV (Eu-154).

Specific activity of Sr-90 and Cs-137 at various depths is shown in Table 31. The highest content occurs in Kainar, for both the surface and the layer at the depth of 20-25 cm.

Table 31. Nuclide Content in Soil at Various Depths in the Subject Areas.

Village/town	Depth (cm)	Isotope activity (Bq/kg) Sr-90	Isotope activity (Bq/kg) Cs-137
Kainar	0-5	14.9	52.0
	5-10	--	--
	10-15	--	--
	15-25	--	--
	20-25	12.4	1.5
Sarzhal	0-5	12.8	12.0
	5-10	13.9	0.7
	10-15	13.9	0.7
	15-25	--	--
	20-25	--	--
Village/town	**Depth (cm)**	**Isotope activity (Bq/kg) Sr-90**	**Isotope activity (Bq/kg) Cs-137**
Tailan	0-5	14.4	11.1
	5-10	--	--
	10-15	--	--
	15-25	--	--
	20-25	--	--
Kokpekty	0-5	5.3	10.5
	5-10	2.6	1.9
	10-15	1.9	0.9
	15-25	1.2	0.7
	20-25	0.4	0.5

According to a 1958 report [9], Sr-90 was present in the soil at Tailan and Kainar in the amounts of 0.6 and 0.2-0.6 Ci/km^2, respectively. The same report established the soil penetration of Sr-90 in Sarzhal, where the 5-10 cm deep layer had twice as much Sr-90 as the 0-5 cm deep layer. Dispensary Number 4's records have 18.95 Bq/kg for Sr-90 content in Sarzhal for 1981 [8-10].

For the 0-5 cm deep layer, the ratio of Cs to Sr is 3.5, 0.94, 1.18 and 1.65 for Kainar, Sarzhal, Tailan and Kokpekty, respectively. Among locally comparable sites, reference can be made to the Cs-Sr ratio lying between 1.3 and 2.07; this was established, according to 1977 archival records, as a result of soil radionuclide determinations at the village of Steklianka, a suburb of Semipalatinsk, and some other localities not in the immediate vicinity of the STS. A general increase in Cs content and the corresponding rise in the element's specific

activity in the soil must have occurred in Semipalatinsk Province--as it has worldwide—in 1986-1987 following the Chernobyl disaster.

The Cs-Sr ratios change, however, with depth. Thus, we have 0.12 (Kainar) at the depth of 20-25 cm and 0.05 (Sarzhal) at the depth of 10-15 cm. In Kokpekty, the ratio is 0.73 in the upper soil layers (5-10 cm), and 1.25 at the depth of 20-25 cm.

A lower migrational ability for Cs-137 is obvious. As to the differences, often measuring an order of magnitude, in the same characteristics between Sarzhal and Kainar, on the one hand, and Kokpekty on the other, this can be imputed to the nuclear tests' fallout.

The rate of migration in soil for Cs-137 from global fallout has been established in the literature to be 0.1 cm per year [11-13]. Over the 50-year history of nuclear tests on the globe, the path traveled by the Cs-137 yield must consequently be within the top five cm of soil depth. The depth at which Cs-137 was found in the subject areas is significantly greater. Our data on the flow density of ß and γ irradiation for various depths (Table 28) provide evidence for radioactivity levels much higher than could be attributed to the background.

Radiation Contamination of Vegetation

The present source of contamination is represented by nuclides in the upper soil layer, which get inside the plant with absorbed nutriments and moisture. Specific radioactivity of plants growing on unimproved pasture lands was determined (Table 30).

Cs-137 content for Kainar is seen to be four to six times higher than anywhere else. In all sites, the Cs content in plants amounts to 5-8% of that in the soil.

Sarzhal and Kainar are similar to each other with respect to Sr-90 content, but both have seven times the level in Kokpekty. The data seem to support a well-known observation that two to three years after a nuclear test, the Sr-90 or Cs-137 transition in plants becomes dependent upon the soil nuclide concentration. The literature shows that plants absorb 3 to 10% of the Sr-90 present in the soil [11]. This agrees quite well with our finding for Kokpekty. In the other three sites, the absorbed proportion of Sr-90 ranges from 25 to 30%. Further studies are required to explain this effect.

The annual absorbed amount of Cs-137 is normally equal to 0.1-0.3% of ingested Sr-90. In Kokpekty, where contamination of plants and soil is due to global fallout, the Cs-137 to Sr-90 ratios are 1.612 for plants and 1.647 for soil.

Historically, the 1958 mission [7] reported the range of Sr-90 content for annual plants in Sarzhal to be 1.8-2.1 MBq/kg of ash. The content of Sr-90 discovered in the fodder corn was 48.1 Bq/kg in Kainar in 1981 [15]. Gusev estimated the content of Sr-90 for grass and dry grass in Sarzhal and Dolon at 1.0 and 1.5 Bq/kg in 1984; the corresponding figures for Cs-137 were 4.7 and 5.0 Bq/kg [16].

Radioactive Contamination of Foodstuffs

The eventual fate of radionuclides after several nuclear explosions over a long period of time is to enter into the human organism via food products. The levels of radioactive contamination of locally produced food products (the population ate almost solely locally made products) and potable water are presented in Table 32.

Table 32. Levels of Long Half-life Nuclides in Food and Water, Bq/kg or Bq/l.

	Sr-90				Cs-137			
Village/ town	**Milk**	**Meat**	**Bones**	**Water**	**Milk**	**Meat**	**Bones**	**Water**
Kainar	+			+	0.044			0.025
Sarzhal	0.514	0.672	12.08	0.583	0.049	0.185	+	0.039
Kokpekty*	0.059	0.029	4.823	0.457	0.069	0.090	1.851	0.005

+ Below sensitivity threshold (Sr-90: 0.02-0.005, Cs-137:0.005-0.002)
-- Sampling was not done
* Average values

It can be seen that the level of long-lived nuclide contamination of food is many times higher in Sarzhal than in Kokpekty, especially with regard to Sr-90. Sr-90 concentration in milk was reported in 1958 [7] to be 74 mBq/l for Sarzhal. The 1981 data on food contamination levels at Sarzhal are given in table 32 [14]. It can be noted that the Sr-90 content recorded for human teeth was around 39.4 Bq/kg.

Table 33. Nuclide Content in Food at Sarzhal, 1981 (mBq/kg (l)).

Foodstuff	Sr-90	Cs-137
Meat	125.8	510.6
Milk	414.4	210.9
Cattle bones	43,993	
Bread	229.4	192.4

The relative intensities of radioactive isotopes migrating up the biological chain (where links are soil → plants → animals → foodstuffs → human beings) are presented in Table 34. The milk-to-fodder ratios are 0.08 and 0.2 for Cs and Sr in Sarzhal. The ratio was measured only for Cs at Kainar and found to be 0.017. The concentration of K-40 in meat and dairy products was found to lie within its usual limits for such foodstuffs.

Table 34. Cs-137 and Sr-90 Content as Ratios of Values for Selected Links of the Biological Chain.

Nuclide	Biochain links	Sarzhal	Kokpekty
Cs-137	Milk/plants	0.06	0.088
	Meat/plants	0.22	0.115
Sr-90	Milk/plants	0.139	0.122
	Meat/plants	0.182	0.060
	Animal bones/plants	3.80	8.29

The data in Tables 32-34 appear to be in agreement with the generally inferred nuclide pathways into the human organism. (See also Tables A7 and A8.) The major nuclide entering human organism with food, and possibly water, is Sr-90. This conclusion is borne out by the finding that Sr-90 accounted for 92-94% of the total nuclide content in humans of the subject areas (calculated values).

It thus follows that the biological threat posed by Cs-137 is comparatively less significant that that from Sr-90. This conclusion seems to be in good agreement with published data on the formation by Cs-137 of virtually insoluble compounds which firmly bind this radionuclide, thereby limiting its motility in soils within narrow bounds; accordingly, the relative uptake of Cs-137 by plants and subsequent transfer to milk is low.

Compared with Kokpekty, the Sarzhal area features Sr-90 levels which are 2.5 and 7 times as high for animal bones (horses) and pasture grass, respectively. Accumulation of Sr-90 in the bone tissue appears to be dependent upon the level of dietary calcium. This warrants further investigation of the changes in the strontium/calcium ratio along the biochain of soil → plants → foodstuffs → human beings.

2.12 Irradiation Doses

External Irradiation Doses

Contributions to such doses come from various nuclides emitting γ rays, but significant contributions are due to only a few of them, notably Cs-137. External dose can be computed on the basis of precipitation density time integral. In the present study, the annual dose due to nuclides accumulated in soil was estimated from products of Cs-137 decay. Results are presented in Table 35.

Table 35. Total Cs-137 in Soil of Towns Studied and Annual Absorbed Dose.

Village/town	Total Cs-137 (kBq/m^2)	Annual absorbed dose (μGy)
Kainar	4.157	38.199
Sarzhal	0.955	8.776
Tailan	0.885	8.132
Kokpekty	0.993	8.473

The external doses for Kainar (from the explosion of 1951), Sarzhal (1953) and Tailan (1953) were officially reported to be 21.5, 66.6 and 277.2 rad (215, 666 and 2772 mGy), respectively [16]. External γ-irradiation doses to be expected for Kainar, Sarzhal, and Tailan along with likely exposure doses following seven ground tests during 1951-1965 were recalculated based on the available archival data (Table 36).

Table 36. Exposure Doses of External γ Irradiation for the Environment and the Population Following Seven Nuclear Tests (mGy environment/mGy population).

Year of Test	Kainar	Sarzhal	Tailan
1951	269/215	432/307	--
1953*	4,123/562	4,818/666	1,8677/2,722
1954	210/145	290/156	--
1955	324/163	368/168	--
1957	185/134	243/156	--
1958	246/158	271/160	--
1965	120/85	324/162	--
Total	5,477/1,462	6,744/1,775	1,8677/2,722

* Adjusted for evacuation of the inhabitants
-- No data

NOTE: Tailan is a small village of roughly 30 inhabitants that received an extremely high level of external γ irradiation after the 500 kt bomb exploded in August 1953. The population was evacuated for 14 days, then allowed to return.

It can be seen that the environmental level of irradiation was around 6 Gy while the population dose was from 1.50-1.80 Gy, not counting internal irradiation. The calculation of the dose from the 12 August 1953 event was done with allowance for evacuation and relocation within 210-350 hours. The actual time span between leaving and coming back was 120-210 hours, which means that the actual dose was at least two times higher than official calculations.

According to official records, contamination was measured only once (1962) in Kokpekty and was 0.3 and 0.2 R for the environment and the population, respectively.

Internal Irradiation Doses

Sources of internal irradiation are airborne nuclides present in the air just above the surface and nuclides lying on the ground surface. The pathways into the human organism are through breathing and consumption of food and water respectively.

The equivalent ingested doses of Sr-90 and Cs-137 are given in Table 37. The findings show that Sr-90 is the prevalent component of the equivalent ingested dose. The Cs-137 contribution measures a few hundredths of a percent: 0.05% for Kokpekty and 0.06% for Sarzhal. The data of the table also make it clear that the total internal dose is 1.6 times as high in Sarzhal as it is in Kokpekty. Dietary differences among the subject areas were ignored in dose computations. Kokpekty produces more vegetables than Sarzhal.

For purposes of comparison, the estimated annual effective equivalent dose of internal irradiation from natural sources in the environment with normal background is 1.34 μSv.

Table 37. Equivalent Ingested Dose Due to Consumed Food Products, in μSv.

		Village/town		
Isotope	**Foodstuff**	**Kainar**	**Sarzhal**	**Kokpekty**
Cs-137	Milk	0.09	0.105	0.149
	Meat	--	0.159	0.092
	Water	0.24	0.367	0.043
	Bones	--	--	0.024
	Total dose	0.33	0.631	0.308
Sr-90 (without allowance for damage factor)	Milk	--	148	16
	Meat	--	78	3
	Water	--	740	583
	Bones	--	14	2
	Total dose	--	980	604
Sr-90 (with allowance for damage factor)	Milk	--	740	82
	Meat	--	389	16
	Water	--	3,700	2,913
	Bones	--	70	10
	Total dose	--	4,899	3,021

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Section 3: Clinical Investigations

3.1 Demographic Background

Contaminated Area

The medical examination was conducted in the villages of Sarzhal and Kainar, which are part of Abai District, a subdivision of (then) Semipalatinsk Province.

According to the 1991 census, the population of the District is 25,800. The Semipalatinsk Institute of Medical Radiology and Ecology's file on the individuals who have undergone direct irradiation as a result of open air STS tests contains 8,000 entries on district inhabitants. Some 12,000 people born after 1965 are descendants from the irradiated persons. About 5,000 have moved here from areas not contaminated by the STS fallout amounts to 5,000.

There are 236 households in Sarzhal, consisting of 4 to 16 members, on the average. The village's population currently is 2,180; the numbers of males and females are roughly equal. The total number of fallout victims and their descendants is 1,840.

The village of Kainar consists of 181 households, with individual families varying in the number of members from 3 to 13. Out of the total of 1,890 inhabitants, 1,690 belong to the group of irradiated persons and their descendants.

The original plan of producing a health chart that would cover the last three generations of a number of sample families did not materialize. What has been accomplished is a complete list of the families where at least one member is a known fallout victim. The data on each family were recorded in the form of more or less detailed individual health histories.

The procedure employed in achieving this, which consisted of interviewing members of each household by workers on the survey missions, appeared to arouse suspicion and anxiety in the inhabitants. The people were not cooperative because of the sensitiveness of such questions as blood relationship to fallout victims or the rate of stillbirths in the family. The subjects also refused to present their children or grandchildren for medical inspection for fear that some latent defects might be discovered. Similar experience had been reported by the previous missions in regard to children with apparent physical or mental defects.

Kokpekty

The village of Kokpekty, which is inhabited by some 6,000 people, is the administrative center of the rural district bearing the same name and having a population of 31,000 people. At least 85% of the village's inhabitants are ethnic Kazakhs living in 642 households.

Geographically, Kokpekty district occupies the south-southeast end of Semipalatinsk Province, bordering East Kazakhstan Province and China. In both climate and socio-economic conditions, the district is little different from the rest of the province. Raising corn and stable livestock and pasturing are the key elements of the economy. Vegetable farming in this area, which is well supplied

with water, makes the problem of vitamin deficiency comparatively less acute. As in Sarzhal and Kainar, there is no sewage system in Kokpekty, and litter, including cattle farm waste, is very conspicuous. The sources of water supply are the river, the wells, and, to a limited extent, a central water supply.

Although for the purposes of the present study the Kokpekty district was selected as a control region, it is not, in the rigorous sense of the word, a nuclear pollution-free area. During the period of atmospheric testing, the district and the village were — as archives testify — subject to 10-70 milliSievert of total external irradiation. The internal irradiation dose, which would be calculated from food products, air and water, was never measured.

The village is located at a distance of some 350-450 kilometers from the tests' epicenter, and its test-related history includes pollution events dated 12 August 1953, 30 October 1954, and 18 October 1956.

The radiation victims register maintained at the National Research Institute for Radiation Medicine and Ecology (NRIRME) now has 9,600 in the "Direct" section and 19,400 in the "Descendants" section. ("Direct" refers to those persons subjected to the effect of irradiation during the period of above ground testing; "Descendants" are their children, grandchildren, great-grandchildren and so on. Descendants who were themselves exposed to above ground testing are included in the Direct category.) The 6,600 immigrants since 1965 are regarded as free from radiation contamination.

A medical check-up of a selection of the Kokpekty population (673 adults and 344 children under 15 years of age) was done in September and October of 1995. The majority of persons examined were in the upper age groups: 17.1% were over 60; 34.7% were between 40 and 60; and 40.4% were 20 to 40 years old; teenagers accounted for 7.6%. In Kokpekty, as nearly everywhere else in Kazakhstan, children accounted for one-third of the total population; 68.4% of the subjects of the survey were female.

Forty persons were able to see only one or two specialists, and so were excluded from the review. The complete examination included general therapy, gynecology, pediatrics, dermatology, mental diseases, oncology, and endocrinology. The team also featured an EKG (electrocardiography) specialist, endoscopist, and ultrasonographer.

The examination was offered on a totally voluntary basis. After a few times it became apparent that the original intent to survey the entire population, including one, two or three generations of a single family, was not feasible because it was seen as culturally repugnant. The observation pattern used was that previously employed in Sarzhal: the initial examination was done by a diagnostician-therapist who charted further visits with specialists.

In an attempt to enhance the depth and accuracy of diagnostic studies, 568 patients were given EKG and echocardiograph tests, and an additional set of 411 were ultrasonographically screened. Endoscopy was applied in 205 cases and was aimed at detecting gastroesophagic neoplasms. Urine and blood tests were almost universally applied.

The morbidity rate in Kokpekty was established at 241:1,000 — a value that is 1.22 to 1.33 times higher than the average determined by Ibraev [1] for the Zhana-Semei and Abai districts.

3.2 Skin and Integument Diseases

Inhabitants of the subject areas vary considerably in general dermapathology rates, specific skin morbidities, and clinical manifestations and trends of dermatoses as well. Relevant morbidity rates are 21.2% at Kainar and 36.3% at Sarzhal, compared to 11.1% at Kokpekty (Table 38). The rates of congenital and autoimmune skin diseases differ between Kainar (4.6%) and Sarzhal (6.6%) on the one hand and Kokpekty (0.6%) on the other, by seven and ninefold, respectively. Sarzhalians were found to be affected more than the other subjects by pretumor and dystrophic dermopathies. The level of three autoimmune diseases of the skin in both Sarzhal and Kainar far exceed the national rate.

Table 38. Diseases of skin and dermal appendages.

Principal types of dermatopathology	Kainar N=408	Sarzhal N=653	Kokpekty N=633
Allergic dermatoses (eczema of various etiologies, dermatoses, neurodermatitis)	41	83	33
Infectious and parasitic skin conditions (pyoderma, mycosis, herpes, pruritus, etc.)	31	74	16
Congenital (bullous epidermolysis, ichthyosis, exudative erythema)	7	21	0
Autoimmune (systemic lupus erythematosis, scleroderma, psoriasis)	12	22	4
Benign neoplastic disease (papillomatosis, keiloidosis, etc.)	6	16	3
Dystrophic conditions (vitiligo, dyschromia, alopecia)	6	10	3
Others	8	11	10
Total	111 (21.2%)	237 (36.3%)	70 (11.1%)

With respect to the frequency and severity of clinical cases, Kokpekty, the control area, falls into the medium group of the national classification. According to the Institute of Ecological and Medical Radiology, the skin morbidity rate in 1991 was 16.3:1,000 for adult Kokpetians, which is 1.5 and 2.0 times lower than in, respectively, the Abai and Beskaragai districts. A skin morbidity survey [2] canvassing 2,238 adults of Semipalatinsk Province established the following rates for the districts: Abai, 36%; Zhana-Semei, 58.4%; Beskaragai, 47.8%; and Kokpekty, 26%. On the other hand, a level of dermatopathy was noted in Semipalatinsk City that would appear to be disproportionately high with respect to the local sanitary-hygienic standards [2].

In Sarzhal and, to a lesser extent, in Kainar, dermatoses would present with allergic manifestations, tend to be frequent and acute, and resistant to therapeutic

measures. The allergic dermatoses, including actinodermatitides, were found twice as often in adults than adolescents and children. However, neurodermatitis, though recorded in adults between 33 and 60 years of age, was found to be more widely spread among adolescents and children. The eczemas were remarkable for their nonclassical clinical course, displaying torpidness and a relative lack of signs of inflammation even in periods of exacerbation.

Among the 21 cases of inheritable dermatopathology recorded in Sarzhal, the ratios of diseased to normal persons with bullous epidermitis and ichthyosis were two to three and one to seven, respectively. In one family, the former disease was diagnosed in three generations (grandfather, three sons and a grandson), and was characterized by uniformly considerable severity. The ichthyosis patients were all female, of 15, 31 and 34 years of age.

In terms of potential radiation-induced health effects, a striking case was found to be presented by N.B., a 36-year old inhabitant and native of Sarzhal. With a history dating from early childhood, the patient, who is a participant in the local medical college's follow-up program, was diagnosed to have total alopecia, diffusive neurodermatitis, reticulosis, devolving folliculitis and enteropathic acrodermitis. Beside an unusually strong susceptibility to dermopathy, the supposed link to a radiation effect is provided by the simultaneously present enteropathy and malfunction of the blood-producing organ.

If the figure of 17.7% established for skin problems following an examination of 335 inhabitants of Kainar in 1957-1959 can serve as a guide, the dermatopathy frequency has at least doubled in the case area over the period of three decades. One area of dermatopathy has seen a reversal of trend, however. In the late 1960s, every fifth Kainarian was noted to have hyperpigmentation of the open parts of the body, and every tenth suffered from early xerosis, hyperkeratosis and cheilitis. The frequency of petechiae, hemangiomas, and telangiectasia was high, especially with regard to hemangiomas [3, 4]. These microaneurysms, which testified to blood vessel atony and particularly that of capillaries, were recorded by the Babayantz mission in every third Sarzhalian and every fourth Kainarian, as compared with a 1:10 ratio established for controls. The present mission's examinations revealed a virtual disappearance of these skin blood vessel disorders in the case areas, with only four cases of dyschromia and three of alopecia detected—a particularly significant improvement for the latter disease when compared to the 1958 diagnosis cohort consisting of 18 young Sarzhalians.

This is all evidence for an important role of the skin as an indicator of the general status of a person's condition. As immunodeficiency increases under the action of adverse factors, allergic pathology is unleashed to become the primary form of skin affections. The skin also bears the brunt of genetic disorders, as is manifest from its congenital illnesses.

3.3 Otorhinolaryngologic and Dental Diseases

The high incidence of otorhinolaryngologic and dental diseases is documented in Kainar and Sarzhal is documented in Table 39. Chronic and subacute tonsillitis, laryngopharyngitis, and sinusitis are widespread, as are dental diseases; caries have been diagnosed in every fourth adult inhabitant, not infrequently in association with periodontitis.

Comparison of pathology with the 1959 data (Table 9) shows that, in addition to quantitative changes, such syndromes as mucous membrane hemorrhage, erosive and/or ulcerous stomatitis have by now disappeared. Simultaneously, the incidence of gingival problems, especially gingival bleeding, has decreased to a considerable extent.

The incidence of otorhinolaryngological diseases in Kokpekty is within the national average, except for chronic and subacute tonsillitis, which occurs 1.3 times for frequently in Kokpekty.

Table 39. Otorhinolaryngological and dental diseases, Kainar, Sarzhal, and Kokpekty (number of cases).

Disease	Kainar (N=408)	Sarzhal (N=653)	Kokpekty* (N=633)
Otorhinolaryngological:			
Pharyngitis, laryngitis	13	20	7
Chronic and subacute tonsillitis	36	40	31
Rhinitis	13	6	9
Sinusitis	9	10	8
Chronic otitis	18	9	4
Hearing impairment	88	10	5
Others	20	21	4
Total	117 (28.7%)	116 (17.8%)	68 (10.8%)
Dental:			
Caries (uncomplicated)	110	87	
Caries with associated pulpitis and periodontal complications	81	61	
Glossitis	12		
Cheilitis	42	24	
Periodontitis	18	13	
Total	263 (64.5%)	185 (28.3%)	

3.4 Cardiovascular Diseases

For the examination program, EKG screening was offered to everyone with a heart condition; this allowed diagnostic verification to be made, the patient's condition to be assessed, and arteriosclerotic and arrhythmic cases to be identified.

According to the classification system used in the former Soviet Union, the diseases of the cardiovascular system are grouped as follows:

- Cardiopathy, directly or primarily resulting from disorders of the heart muscle or vessels

- Neurocirculatory dystonia, which is related to functional or morphological disorders affecting peripheral vessels and the vegetative nervous system

Belozerov et al. [5] has estimated that cardiac diseases account for 46% of terminal diseases in Kazakhstan, with the corresponding figure for the NIS (CIS) countries being 52%. This estimate is based on a nosological concept of uniting the cardiac diseases proper (the subject of the present survey) and various vascular disorders into one category.

Raisov [2] cites the rate of 51.5:1,000 for cardiovascular diseases in Semipalatinsk Province. According to the same author, the rates of hypertension and ischemia are 12.9 and 5.6 per 1,000, respectively. The rural areas, however, stand out compared with the average for the entire province: the rates for these rural districts are: Kokpekty 87.3 per 1,000; Abai 98.6; Beskaragai 118.6; and Zhana-Semey 175.4 per 1,000. The present study differs from Raisov's in that cardiac diseases and strictly vascular cases were studied separately. If combined, the total number of cases would correspond well with Raisov's estimate.

3.5 Cardiopathy

The Soviet school of therapy regarded cardiodystrophy as an illness with an independent course; that is, the primary degeneration of the heart muscle is not causally related to organic alterations in the organ or the vessels, but is due instead to metabolic, i.e. myotropic, disorders. The most widely accepted causes of myocardial dystrophy included vitamin B and C deficiency, thyrotoxicosis, different intoxications, chronic infectious processes, and various anemias.

Myocardiodystrophy has for its specific symptom cardiodynia, particularly after exertion, often associated with rapid heartbeat, short breath and easy fatigability. The diseases' differential diagnosis recognizes such features as muffled heart beat, heart enlargement and EKG evidence of myocardial alterations.

More than half (53.7%) of Kainarians are heart patients. The rates for Sarzhal and Kokpekty are somewhat lower: 41.9 and 43.4% respectively (Table 40). The incidence of cardiovascular diseases in Kainar and Sarzhal has decreased when compared to the data reported for the same localities by Pityushin and Sabdenova in 1960 [6]. Out of the authors' clinical examination of 726 people, 64.6% were affected with cardiovascular diseases. Interestingly, 57.2% of 416 persons examined in the control village of Shchadra, Pavlodar Province, were also affected with cardiovascular disease.

Table 40. Incidence of heart diseases in Kainar, Sarzhal, and Kokpekty (number of cases).

Disease	Kainar (N=408)	Sarzhal (N=653)	Kokpekty (N=633
Ischemia	47	42	31
Stenocardia (angina pectoris)	21	18	18
Cardiosclerosis	32	40	32

Table 40. (continued)

Disease	Kainar (N=408)	Sarzhal (N=653)	Kokpekty (N=633
Myocardiodystrophy	27	67	88
Hypertension	80	81	74
Vasculopathy and arrhythmia	11	24	26
Other heart disease	1	2	6
Total	219 (53.7%)	274 (41.9%)	219 (53.7%)

Myocardiodystrophy occurs roughly 2 and 1.3 times more frequently in Kokpekty than in Kainar and Sarzhal. Ischemia, stenocardia (angina pectoris), or cardiosclerosis was observed in every fourth Kainarian (24.5%), while only in every seventh and eighth inhabitant of Sarzhal and Kokpekty, respectively.

In both Kainar and Sarzhal, a sex difference in the level of ischemia was noted, with the number of men affected being twice the number of the women of the same age. Among males, there was an age difference in the incidence of stenocardia (angina pectoris); it was seldom seen before middle age. In Kokpekty, a tendency for the vasculopathy rate to increase with age was noted: 329 people over the age of 40 were found to be affected with cardiovascular diseases (cardiosclerosis, ischemia, myocardiodystrophy, hypertension). Heart trouble of some kind was found to be universal for the age group over 60. Within the age brackets of 51-60 years, the rate of morbidity was 62%, and it was 50% for the group between 41 and 50 years of age. A quarter of people in their thirties were diagnosed for hypertension and stenocardia (angina pectoris).

Researchers have found [7] that ischemia and infarction tend to affect Turks, the indigenous population of Central Asia, to a much lesser extent than ethnic Slavs. This finding is borne out by the 1982-1985 admissions statistics of the Semipalatinsk cardiological hospital: the ethnic Kazakh contingent comprised as little as 5.3% of the total [8]. This hospital serves not only the residents of the city, but also of the entire province. Thus, all patients with myocardial infarction and ischemic heart disease are referred to this institution.

As for ethnic composition, Kazakhs comprise close to 50% of the population of Semipalatinsk city, and close to 70% of the population of Semipalatinsk Province. The Turkic peoples (Kazakhs, Kyrgyz, and others) as well as the Mongol population have a low incidence of ischemic heart disease and hypertension, despite the copious use of meat. However, one should note that over the past several decades, the incidence of cardiovascular diseases in the Turkic ethnic groups residing in cities has been rising. Thus, the authors submit that the change in the way of life, eating habits, and psychological factors can affect the frequency of cardiovascular pathology.

3.6 Neuropathy

The procedure adopted by the mission was to do neuropathologic evaluation during the overall examination and, when required, to refer the patients to the

specialist neuropathologist for further management. In addition to the clinical history, diagnosis was formulated on the basis of somatic innervation evidence and response of the vegetative neural system, including eye and heart, clinostatic (recumbent) and orthostatic reflex action, dermographism, and response to mechanical stimulation.

The diseases of this group, which include vegetovascular dystonia, astheno-neurotic syndrome, and neurocirculatory dystonia (NCD) syndrome, stem from dysfunction of the vascular channels. Therapeutically, the observed functional disorders have been classified as follows:

1. Mild functional disorders of the nervous system. In this group are included features which have functional disturbances of the neurological status, not noticeably influencing the patient's capacity to work.
2. Vegetovascular dystonia (VVD). This group includes features with signs of vegetative disturbances, including migraine-like syndrome, indicated by the presence of early stages of compensated insufficiency of the cerebral circulation. According to neuropathological opinion, in more than 60% of cases and irrespective of age, VVD is considered a sequellae of chronic tonsillitis.
3. Asthenic nervous syndrome. Here are patients regarded as having an easily exhausted nervous system upon testing.
4. Neurocirculatory dystonia (NCD). Symptomatic NCD is similar to signs described in VVD. These two similar entities comprise by far the major part of nervous system diseases (35-45%). Clinical manifestations of NCD vary, beginning with a light form (asthenia) with transitory cardiovascular dysfunction and ending with conditions of considerable gravity, such as dyscirculatory encephalopathy, which leads to intracranial hypertension. In all of its varieties, NCD is accompanied by dystonia of the venous channels and increased elastoviscosity of arterial vessels. Patients take these complaints to both cardiologists and neuropathologists.

The Sarzhal neuropathologist-managed group numbered 105 females and 98 males (31.24% of the total number) grouped as follows: under 14 years, 24 patients; 15-30, 45 patients; 30-60, 105 patients; and over 60, 29 patients. Out of the total of 408 people examined in Kainar, 82 were referred to the neuropathologist; in others, neuropathologic syndromes were routinely recorded as part of the general physician's examination.

The level of neuropathy in Kainar (66.7%) was notably higher than in Sarzhal (55.6%), while nearly every other Kokpektyan (47.1%) was a neuropathic patient (Table 41). The diseases related to neural affections were quite common in Kokpekty, including sciatica, plexitis, neuralgia, and posttraumatic and postinfectious disease conditions. The overall rates of neurocirculatory dystonia are twice as high in Kainar and Sarzhal as in Kokpekty, and when one considers only those with severe dysfunction, the rates are 2.8 and 2.3 times as great, respectively.

Table 41. Distribution of nervous system disorders by diagnostic groups.

Nosology by degree of severity	**Kainar (N=408)**	**Sarzhal (N=653)**	**Kokpekty (N=633)**
Mild dysfunction: asthenia	8	22	6
Pronounced Dysfunction:			
Vegetovascular dystonia	26	69	11
Asthenovegetative syndrome	40	51	31
NCD syndrome	67	93	72
Severe dysfunction:			
Dyscirculatory encephalopathy	32	42	18
Subtotal	173 (42.4%)	277 (42.4%)	138 (21.8%)
Organic Disorders:			
Vascular disease	20	12	16
Cerebral atherosclerosis	44	33	21
Others (sciatica, neuralgia, traumatic injuries, and infectious disease sequellae)	35	41	123
Subtotal	99 (24.3%)	86 (13.7%)	160 (25.3%)
TOTAL	272 (66.7%)	363 (55.6%)	298 (47.1%)

NCD appears to be a leading disease, accounting for approximately one-fourth of the total, followed by VVD. The NCD rate at Kokpekty is 1.6 and 2 times lower than in Sarzhal and Kainar, respectively. Moreover, dyscirculatory encephalopathy occurs 2.8 and 2.3 times more often in these areas than Kokpekty.

In persons over 40 with NCD, the course of the disease primarily had aspects of nervous system dysfunction and was often diagnosed as dyscirculatory encephalopathy. In persons under 40, the disease occurred twice as often in females than in males; over 40, the incidence was similar in both sexes.

The high rate of nervous system dysfunctions around the STS was first noted during the first medical expeditions in 1958-1959. The clinical pathology varied widely, and the same disease may have been referred to as asthenovegetoneurosis in some cases, and in others called vegetodystonia or nervous debility, depending on the predominant symptoms. The high NCD frequencies recorded for Kainar and Sarzhal were 76.6 and 66.3%, respectively (Table A10) [9-11].

In comparison with data from the expeditions of the Kazakhstan Academy of Science and Moscow Institute of Biophysics in 1957-1959, the present mission's data indicate a significant improvement in the state of the case population's neurological health. The rate of malfunctions has decreased by 1.5 times, although there has been a slight increase in the incidence of cerebrovascular disease noted for Kainar.

Data of Ibraev [1], which are based on official statistics and cover recorded diseases of the nervous system, suggest that the rate of such diseases in Kokpekty district is 1.6 times higher than in Beskaragai and is 3.5 times higher than the rate recorded for Abai. The practice in use until recently was to group nervous system dysfunctions with cardiovascular disorders. The NRIRME report for 1993 cites 7.5 and 50.6 per 1,000 as rates of nervous system diseases for Kokpekty and Abai districts respectively.

3.7 Arterial Blood Pressure

Nearly all cardiovascular disorders and other somatic conditions arise and develop from vessel pressure deviations. Blood pressure (BP) is an integral indicator of the general state of the cardiovascular system.

The initial investigators of BP at Sarzhal and Kainar [12] showed that over half of all adults suffered from hypotonic dystonia at systolic pressures below 101 mm. When measured again the following year, hypotension was found to affect 63.2% (systolic pressure) and 43.2% (diastolic pressure) of Sarzhalians, compared to the respective percentages of 32.4% and 29.6% for Shchadra. The hypertension rate was 3% in Sarzhal at the time [13]. Further surveys documented a rapid conversion of hypotension to arterial hypertension. Thus, the percentage of Sarzhalians with hypotension decreased from 46.1% in 1958 to 17.5% by 1966 [14]. The number of hypertension cases (systolic pressure >140 mm) had more than doubled, to 6.9%.

The study of BP time variation over a period of 35 years (1958-1994) shows a clear trend for hypotension to convert to hypertension. This trend is shown for all age groups, being less manifest for the 20-29 age group, but more pronounced for those 40 to 49 years old. BP measurements taken in Kainar and Sarzhal testify to the prevalence of hypertension over hypotension, with respect to both systolic and diastolic pressures. Age distribution of BP levels is given in Table 41. Three rounds of measurements were made in 1012 inhabitants of Kainar and Sarzhal and in 600 Kokpektians.

Because of a lack of distinction in the classification of the two hypertonic conditions, the cases of symptomatic hypertension were included in the stenocardiac group. Kainarians seemed to be more affected with hypertension than Sarzhalians, with the percentages being respectively 19.3% and 12.4%, although this difference is not statistically significant. Hypertension occurs 1.1 and 2 times less frequently in Kokpekty than in Sarzhal and Kainar.

Hypertension syndrome (systolic pressure over 140 mm) occurs in Sarzhal and Kainar at a rate 1.6-1.7 times higher than in Kokpekty for all ages except the 20-29 age group. The BP standards in Kokpekty are close to the national average.

Table 42. Arterial blood pressure levels by age (%).

		Age Groups							
		Kainar and Sarzhal				Kokpekty			
	mm Hg	20-29	30-39	40-59	50-59	20-29	30-39	40-59	50-59
Systole	> 140	8.5	21.2	38.6	48.5	8.0	13.1	22.6	30.1
	101-139	72.1	63.1	52.1	42.1	75.3	60.3	57.4	58.9
	< 101	19.4	15.7	9.3	9.4	16.7	26.6	20.0	11.0
Diastole	> 90	9.1	29.6	41.3	45.4	6.1	13.1	20.4	22.3
	61-89	73.1	61.4	43.1	40.2	79.2	67.8	58.6	61.3
	< 60	17.8	9.0	15.6	14.4	14.7	19.1	21.0	16.4

3.8 Endocrine Diseases

The endocrinopathy status of the subject populations is roughly the same: from 25.9 – 32.4% morbidity rate per cohort. However, this rate by far exceeds the national average. Pancreatic and pituitary gland disorders, including obesity, occur at a rate of 3.8% in Sarzhal and at twice that rate in Kainar. The rate in Kokpekty falls between the two at 5.5%.

The leader in the frequency of pathology is the thyroid gland. Along with trivial diffuse goiter, with and without secretory malfunction, thyroid diseases noted include autoimmune thyroiditis characterized by variability of the effect produced on functioning of the thyroid gland. No cases of thyroid cancer were detected. This may be due to the rarity of this disease in Kazakhstan (1 case per 200,000-300,000 population).

One in four Kokpektians suffers from some pathology of the thyroid. Middle-aged people constitute the majority of the cases. All cases of hypothyroidism were found in the 40-50 age group. The goiter rate was not unexpected; Kokpekty has long been a goiter endemic area. A 1989 survey came up with a rate of 29.8% for a group of 1,548 people examined [15].

Our findings are consistent with those of an endocrinological survey conducted by Espenbetova [15] in Semipalatinsk Province in 1990-1992. The 38.2% frequency of Stage I-IV goiter reported in that study slightly exceeds the rate we have observed in Sarzhal (Table A11). The incidence of goiter in Sarzhal was established by Espenbetova to be 2.8 times higher with women than with men, a tendency that also applies to Kokpekty.

Archival analysis of the present study revealed a time dependence describing the goiter incidence in Semipalatinsk Province. The decade of 1978-1988 witnessed a rise in the disease frequency by 20.8% in Sarzhal, 40% in Vladimirovka, and 7-8% in Kokpekty. An increase up to 75% was recorded for Dolon STS fallout victims as compared to a mere 22.6% for settlers since 1965.

The time dependence of thyroid disease incidence noted by Espenbetova for contaminated areas differs considerably from the prevailing patterns of Kokpekty district and the city of Semipalatinsk. The goiter incidence recorded for Kokpekty in 1982 was 2.5-3.5 times higher than in the Abai, Zhana-Semey, and Beskaragai districts (Table 12). By 1992, however, goiter morbidity in

those districts had risen to the level in Kokpekty (100 cases in Kainar, 144 in Sarzhal, and 162 in Kokpekty), and the nodular variety had become twice as frequent (Table 43). Fitting in the trend is a 1.3-fold excess incidence in the city of Semipalatinsk of thyrotoxicosis of high and middle degrees of severity compared to the areas of supercritical and critical radiation risk levels, with the reference city (Semipalatinsk) being an area of increased risk itself.

Table 43. Endocrine diseases detected in the subject areas.

Diseases and Syndromes	Kainar N=408	Sarzhal N=653	Kokpekty N=633
Autoimmune thyroiditis with:			
Thyrotoxicosis	9	4	7
Hypothyroidism	8	5	7
Normal thyroid gland		24	2
Nodular goiter formation	8	12	6
Diffuse nodular goiter	21	17	28
Diffuse goiter with:			
Pronounced toxicity	8	10	14
Normal thyroid gland	48	72	98
Diabetes mellitus	12	9	13
Glucose intolerance		1	
Hypopituitarism	3	4	2
Chronic adrenal insufficiency		1	1
Obesity	15	10	19
Total:	132 (32.4%	169 (25.9%	197 (31.1%)

The cause of the elevated incidence of thyroiditis in populations that have experienced critical and subcritical levels of external ionizing radiation exposure might best be considered in terms of the iodine theory, which postulates a causal relationship between endemic goiter and an iodine-deficient environment. The possible role of autoimmune thyroiditis in the increasing frequency of diffuse goiter is an important subject for discussion. However it raises the next question of why the frequency of autoimmune thyroiditis has increased.

Neither the natural or climatic characteristics of the Semipalatinsk province, nor the known content of micro-elements in its soils can assign the area to the status of a thyroid endemic region. The existing iodine content in the soils, which is 1,000 to 2,000 μgram/kg, may at worst be defined as mildly deficient. In their turn, the levels of the elements copper and cobalt reach 3.9 to 45.4 and 1.9 to 10.8 mg/kg of soil respectively. The soils are deficient, however, in mobile cobalt. The range of iodine concentration in the drinking water is 6.0 to 10.0 μgram/l.

A microelemental study by Espenbetova [15] of 97 locally consumed food items indicated a small iodine deficiency versus a moderate excess of manga-

nese. Iodine ingestion rates measured 58.9 μg/l at Kokpekty and 89.6 μg/l at Abai and Zhana-Semey.

Even though thyroiditis was observed among inhabitants of the desert and steppe areas around the STS in the past, its low rate had never prompted any special medical concern. A reversal in the frequency trend of the disease among the exposed populations took place in the 1970s, or perhaps even earlier.

When viewed in the context of the STS activities, the occurrence of this break-point makes a strong case against the assumption of the disease's origin being due to microelement deficiency. Moreover, evidence has accumulated that points to a different source for the recent surge of thyroiditis in the STS contamination risk area. Namely, in a representative study conducted in Semipalatinsk City by Rozenson [16] and involving 183 people, 23 (or 12.2%) were found to be serologically positive for anti-thyroid antibodies. Espenbetova's study [15], in its turn, established a thyroglobulin content in the blood of 30- to 60-year-old Sarzhalians that was 1.7 times that of Kokpektians. This hormonal product of thyrocytes is known to promote auto-immune thyroiditis in the presence of deficient immunoreaction. Both in Kainar and Sarzhal, as compared with Kokpekty, the researchers also found a threefold to fourfold raised level of blood thyrotropin, a hormone whose hyperproduction is evidence of open or latent hypothyroidism [17, 18]. Of course, elevated blood thyroglobulin can also be due to iodine deficiency goiter or thyroiditis; we cannot confirm or negate this possibility from our data.

3.9 Psychological Diseases

Psychoneuroses are three times less frequent in Kokpekty than they are in Sarzhal and half the rate in Kainar (Table 44). It will be noticed that Kokpektians are free from some of the syndromes. On the other hand, the 32 entries under Sarzhal should be supplemented with three cases of obsession, six neurasthenics, and 13 people suffering from acute encephalopathy (some as post-traumatic sequellae). The data seem to be in agreement with Alimkhanov's survey of Sarzhalians carried out in 1990 [19] when 40 mental cases were identified. The survey also provides some comparative data on the psychopathic morbidity as a function of distance from the Semipalatinsk Test Site (Table 45).

Table 44. Major psychoneuroses observed in the subject areas.

Major Psychoneuroses	Kainar N=408	Sarzhal N=653	Kokpekty N=633
Schizophrenia	4	10	1
Epilepsy	3	5	4
Oligophrenia	10	11	5
Down syndrome	1	1	--
Early childhood autism	1	1	--
Psychopathy	4	3	--
Paranoid depression	1	1	--
Total	24	32	10

The psychopathy rate given by official statistics for Kokpekty district is 6:1,000, which is 2.0, 2.5 and 3.0 times lower than for Charski, Zhana-Semey, and Abai districts, respectively. Oligophrenia, Down syndrome, and psychopathy occur at a rate three times higher at Kainar and Sarzhal than at Kokpekty, being predominantly an affliction of the younger generation; schizophrenia and epilepsy appear to be unrelated to age.

Table 45. Psychiatric morbidity as a function of distance from the nuclear test site, 1990.

Village/town	Distance (km)	Population	Number of cases	Rate per 10,000
Sarzhal	60	2,485	40	160.9
Kainar, Abraly, Medeo, Akbulak, Sargaldak	60-120	8,477	104	122.6
Karaul, Olzhebi, Brlyk, Kulma	120-150	15,777	124	78.6
Arkhat, Kundyz	>150	4,429	51	110.6
Total		27,422	319	115.6
Semipalatinsk Province				157.7
Republic of Kazakhstan				157.6

Source: Alimkhanov [19]

3.10 Diseases of the Alimentary Canal

Diseases of the alimentary canal are widespread in the subject areas (Table 46). In Kokpekty, the percentage of individuals totally healthy in this regard would not exceed 20-25%. Gastritis is the most common condition, followed by gastroduodenitis. The former disease was routinely diagnosed on the basis of characteristic complaints. However, 16 cases in Kainar and 28 cases in Sarzhal were given a fiberoptic gastroscopic examination followed by a cytological examination of the biopsied specimen. This provided a basis for verification of the clinical diagnoses and allowed the severity of the affliction to be assessed.

Table 46. Diseases of the alimentary tract in the subject areas.

Disease	Kainar N=408	Sarzhal N=653	Kokpekty N=633
Esophagitis	12	9	15
Chronic gastritis, gastroduodenitis	176	146	140
Enteritis	--	6	11
Erosive and ulcerative disease of the gastrointestinal tract	7	13	15

Table 46. Continued

Disease	Kainar N=408	Sarzhal N=653	Kokpekty N=633
Chronic cholecystitis, gallstones, biliary tract dyskinesia	74	106	142
Chronic hepatitis	28	32	45
Chronic pancreatitis	50	45	61
Chronic colitis (including spasmodic), large intestinal dyskinesia	71	50	53
Hemorrhoids	4	10	11
Total	422	417	493

Inflammation of the bile passages, hepatocholecystitis, and hepatopancreatitis were diagnosed in every third inhabitant of both Kainar and Sarzhal. Chronic cholecystitis, with and without gall stones, and biliary tract dyskinesia were recorded in every fifth adult subject in Kokpekty. In many cases, verification of the diagnosis was done ultrasonically.

Chronic hepatitis is anything but unusual in rural areas, which typically lack adequate sanitation and drinking water processing. The observed rate of chronic pancreatitis points to prior toxic and infectious diseases left without proper treatment and cure.

There was no difference in female versus male incidence rates of gastroduodenal diseases. This was not so with diseases of the bile passages or hepatitis and pancreatitis, where female rates were twice as high as for males. The rates were also very high for biliary tract disorders, chronic hepatitis, and pancreatitis, with a male:female ratio of 1:2.

For comparison, the 1959 data from the expedition of the Kazakhstan Academy of Science and the USSR Institute of Biophysics of the Ministry of Health showed that the rates for gastric disorders were 7.7% and 8% at Kainar (N=375) and Sarzhal (N=334). The 1960 survey by Shorokhov [13] demonstrated generally similar rates.

3.11 Urologic and Nephrologic Diseases

Patient examination and study of medical histories were combined with dipstick (specific gravity, proteinuria, pH) and microscopic urinalysis, as well as ultrasonography of kidneys (in the case of stones, nephrosis, and nephritis).

Every second Kainarian and every third Sarzhalian has a urinary tract disease, while the rates for Kokpekty are, respectively, 2.3 and 1.4 times lower. Nephrologic diseases account for about half of all urinary tract disease cases at each village. Urolithiasis and urolithic diathesis are also common, especially at Kainar (Table 47).

Table 47. Urological disease incidence.

Disease	Kainar N=408	Sarzhal N=653	Kokpekty N=633
Chronic nephrosonephritis	21	--	17
Chronic pyelonephritis	95	104	88
Urolithiasis	13	10	15
Urolithic diathesis	53	46	32
Subacute cystitis	10	9	11
Prostatitis	13	23	5
Prostatic gland adenoma	14	20	7
Kidney cyst	3	4	6
Total	222 (54.4%)	216 (33.1%)	181 (28.6%)

In the former USSR, urologic and nephrologic diseases (grouped as uronephrologic diseases) were treated, for statistical purposes, within the class of urogenital diseases. On this premise, the 1991 record of urogenital diseases was 43.6:1,000 for Abai, 34.5:1,000 for Zhana-Semey, and 28.6:1,000 for Kokpekty district [1]. Although the diseases of the genital organs proper are not represented separately in this statistical record, their incidence can be surmised on theoretical grounds.

From the records of the 1957-1959 missions, on the other hand, it is clear that urogenital diseases were not a concern of this proportion. The 1960 survey by Petyushin and Sabdenova [4] could identify no more than 106 urogenital cases among the 726 Kainarians and Sarzhalians examined. Clinical examination of these cases showed that 103 people (14.2% of the total number examined) had actually one or more forms of renal disorder, mostly chronic nephrosonephritis and pyelonephritis. In contrast, urocalculous disease could be diagnosed in only a few individuals.

3.12 Gynecological Diseases

The gynecological examination was based on mirror inspection, medical history, and observation. All women over 30 years of age were given a Pap test.

Gynecological diseases appear to affect the majority of women at Kainar and Sarzhal. Sometimes two and even three diseases were diagnosed in one patient, so that the total morbidity number is in excess of the number of surveyed women (Table 48). The proportions of gynecologically healthy women at Kainar, Sarzhal and Kokpekty are 22%, 28% and 61% respectively.

Table 48. Diseases of female reproductive organs.

Disease	Kainar N=124	Sarzhal N=295	Kokpekty N=380
Colpitis (including infectious)	41	120	17
Endometritis, hypertrophic	5	9	11
Chronic adnexitis	32	54	42
Cervicitis	19	32	17
Endocervicitis	6	16	6
Fibrocystic changes of the ovary	4	5	--
Cervical canal polyps	2	2	6
Uterine fibromyoma	8	10	4
Posthysterectomy changes (radical hys-terectomy for cancer)	5	7	2
Displaced sex organs	3	11	7
Uterine prolapse and varicose labial veins	5	7	7
Total	130	273	119

The colpitis observed in middle-aged women was treated as age-related unless of an inflammatory character. The majority of the 38 cases in Sarzhal of colpitic disorders were degenerative in nature and detected in women between 40 and 55 years of age, half of whom were multiparaous, providing evidence for an early involution of the genital organs. The colpitis rate detected at Kokpekty was two to three times lower than at Kainar or Sarzhal, while senile colpitis was not found.

The incidence of lesions in childless women under 19 was recorded in both Kainar and Sarzhal. Habitual miscarriages cases numbered eight, and primary or secondary sterility was claimed by an additional 14 women. Pregnancies, of which the total number among the inspected was 18, were, on the basis of primary examination, proceeding normally. Sexual violations were brought up by young women in 12 instances. In Kokpekty, three patients were prone to miscarriages, and primary and secondary sterility were recorded in eight cases.

Among younger women, menstrual cycle irregularities, ranging in duration from 8 to 36 months, were observed in six cases in Kainar and Sarzhal and were noted in four women in Kokpekty.

The onset of menstruation (menarche) is delayed at Sarzhal, compared with Kokpekty, in some cases not occurring until the age of 24 (Table 49). At the same time, 74.4% of Sarzhalian women become menopausal prior to age 42, twice as many as at Kokpekty. These data were gathered through abstracting the records of the local health center and are not comprehensive, since this survey covers only the women who apparently had a reason to see the doctor on this exclusively voluntary examination.

Table 49. Age distribution of menarche and menopause at Sarzhal and Kokpekty (in percentages).

	Age at menarche					Age at menopause			
	12-14	15-16	17-18	19-20	21-24	34-38	39-42	43-46	>47
Sarzhal	14.3	62.7	11.7	4.1	7.1	6.1	68.3	17.3	8.1
Kokpekty	19.1	75.6	4.0	1.3	--	2.6	34.2	47.4	15.8

3.13 Infectious Diseases

Pulmonary Tuberculosis

In Kainar, the numbers of tuberculosis outpatients and carriers are, respectively, 41 and 5. The group of chemotherapeutic convalescents numbers 12 adults and 7 children. For financial reasons, no lung screenings have been conducted over the past two years, while the traveling herdsmen had their last fluoroscopy some four years ago. Some people conceal the fact of their illness, so that the true TB incidence currently remains unknown. There is phthisiatric evidence suggesting an unusually low sensitivity to tuberculin in the population of Sarzhal; out of the hundreds of the children screened, not a single one revealed a hyperergic response.

Fifty two Sarzhalians are currently tuberculosis outpatients, with two of them carrying active disease bacilli. The list of post therapy cases with residual pulmonary changes includes 18 adults and 12 children. Six additional individuals required preventive therapy, but the treatment had to be discontinued because of a lack of medication.

Lymphadenitis of obscure etiology, associated with subfebrile body temperature and slightly elevated ESR, was noted in 9 and 16 children in Kainar and Sarzhal, respectively.

At the time of the mission, the TB patients at the Kokpekty district hospital numbered 12. The number of TB outpatients was 38. The survey revealed five cases of latent tuberculosis and one case of tubercular lymph nodes of the neck.

In 1959, the level of TB was established by the mission at 20.2% and 10.4% for Kainar and Sarzhal, respectively, with the corresponding numbers of the people examined being 322 and 364. Verification of diagnosis at that time was by means of X-rays [20].

Brucellosis

Except for brucellosis, the population in Kainar and Sarzhal was, to the best of our knowledge, free from infectious diseases during the summer and autumn of 1994. Brucellosis, which was diagnosed on the basis of clinical symptoms and allergic/serologic response, was detected in 83 Kainarians and 73 Sarzhalians. There were twice as many cases among females as among males. Approximately 10% of the cases were children between 8 and 14 years of age. The chronic form of the disease was prevalent, with afflictions of the motor support apparatus such as marked and/or persistent polyarthralgias, periarthritis of the scapula, and knee joint arthritis. Half of these cases of brucellosis were suffering from micropolyadenitis, easy fatigability, and excessive sweating.

It was noted that the frequency of the primary chronic form of brucellosis was high, accounting for 40% of those with this disease. The most involved joints were the smaller articulations of the hand in women and the shoulder girdle apparatus in men. In Kokpekty, chronic brucellosis was diagnosed in 41 individuals, with one subacute case.

The 1959 brucellosis prevalences for Kainar (N=366) and Sarzhal (N=365) are 42.2% and 35.3%. The diagnosis and the severity of condition were then, as on subsequent examinations, determined from Burnet skin test and serologic agglutination by the Heddleson test. Three degrees of the disease were distinguished: weakly positive, positive and strongly positive. If the cases falling within the first category are neglected, the number of cases were, respectively, 93 and 35 in Kainar and Sarzhal in 1959.

The clinical peculiarities noted in Kainar and Sarzhal were associated vascular hypotonicity [21] and, in every third case, an abnormally high rate of increased vascular fragility of the skin vessels in response to negative pressure. The level of vascular disorders displayed by brucellosis patients in the subject areas was two to three times higher than in the rest of Kazakhstan [22].

3.14 Degenerative-Destructive (Collagen-Vascular) Diseases

This grouping combines afflictions of the connective tissue, which generally are confined to joints and articulations. In most cases, these are autoimmune diseases of a degenerative and destructive nature involving collagen and vascular structures.

Generally a common condition in all of the subject areas, this class of ailments appears to be twice as frequent at Kainar as it is at Kokpekty. The most frequent occurrence is osteochondrosis. Rheumatism and polyarthritides of rheumatoid and other origin were diagnosed at Kokpekty in 22 patients (3.5%), while the numbers of such patients were two and three times as great at Sarzhal and Kainar, respectively (Table 50). The same ratio applies with regard to deforming arthrosis. Specialized surveys [1] indicate that rheumatoid arthritis occurs 9 times as frequently at Abai (1.06:1,000) as it does at Kokpekty (0.11:1,000). It is important to note that in the Abai region, clinical examinations of patients with rheumatism show rapid involvement of the internal organs and early appearance of irreversible destructive changes of bone and cartilage.

Table 50. Degenerative-destructive (collagen-vascular) diseases.

Disease	Kainar N=408	Sarzhal N=653	Kokpekty N=633
Rheumatism	5	4	14
Rheumatoid arthritis	18	15	4
Polyarthritis of various etiologies	20	21	4
Degenerative metabolic arthroses	42	40	39
Deforming arthroses	23	56	16
Osteochondrosis	154	147	128
Total	262 (64.2%)	283 (43.3%)	205 (32.4%)

The most frequently affected areas include intervertebral disks with adjoining tendons and capillary-connective tissues of the joints. In both Kainar and Sarzhal, every third inhabitant has been found to be suffering from either osteochondrosis or osteoarthrosis. While there is no difference by sex in the frequency of osteochondrosis of the neck, the spinal variety of the disease is three times as frequent with men as it is with women of the same age. In terms of age distribution, the osteochondrosis cases are bracketed inside the 30- to 60-year-old group, with comparatively much lower frequencies at other ages. All cases were older than 20.

Acute auto-immune diseases and the group of ordinarily heritable diseases are diagnosed primarily as dermatological disorders and have been discussed above.

According to Ibraev [1], the diseases of bones and muscle and connective tissue have a rate of 20.9:1,000 in Kokpekty district, while in Abai and Beskaragai districts the relevant rates are 46.3 and 56.2 per 1,000, respectively.

3.15 Eye Diseases

Compared to Kainar or Sarzhal, eye morbidity at Kokpekty (8.4%) occurs half as frequently, mostly because of fewer cases of conjuctivitis and blepharitis (Table 51). As can be seen, the detected total of eye diseases (53) in Kokpekty is within the national average.

Table 51. Incidence of eye diseases among adults.

Disease	Kainar N=172	Sarzhal N=487	Kokpekty N=411
Cataract	17	48	8
Glaucoma	7	10	6
Keratitis	4	9	5
Persistent disk and optic nerve atrophy	2	5	1
Retinal degeneration	1	3	--
Conjunctivitis	17	28	8
Other diseases	29	27	24
Total	77 (44.8%)	130 (26.7%)	52 (12.7%)

The rates for cataract and keratitis are similar in all three subject towns and appear to be comparable with the national average. At the same time, when compared to the former USSR average [23], the cataract morbidity detected is 3.7 times as great (36.3:10,000). The relevant rates for Kokpekty, Abai and Beskaragai are 65, 123 and 178 cases per 10,000, respectively [1].

Cataract was diagnosed in 17 persons of Kainar (9.9%) and in 48 inhabitants of Sarzhal (9.8%). It was found to be predominantly an old-age illness afflicting mostly women; no case under 40 was recorded, and the male-to-female ratio was 1:2.

The unusually high cataract rate (32.9:1,000) from the village of Kokpekty

may be due to a screening phenomenon, despite our efforts to obtain a random sample. This village does not ordinarily have a physician. The rate of cataract for Kokpekty district is 6.5:1,000, as cited by Raisov. In the former USSR, the rates of cataract and glaucoma were, respectively, 3.8 and 4.8 per 1,000. In Kokpekty, the glaucoma rate is 3.8:1,000; this agrees with Raisov's figure of 4.2 per 1,000.

Ibraev [1] reports that in 1986-1988 the cataract rate (per 1,000) was 133.3 in Semipalatinsk Province, to be compared with the official statistical record of 94.2:1,000 for 1991. As far as Kainar and Sarzhal are concerned, this is in agreement with our findings (98/1,000); the rates for Abai and Kokpekty Districts are even lower, being respectively 81:1,000 and 59:1,000. In contrast, the cataract incidence in Beskaragai reaches the rate of 178:1,000; in Novashulba it is also high—123:1,000.

Glaucoma is twice as frequent in Kainar (ten cases, or 4.1%) as it is in Sarzhal (seven cases, or 2.1%), where it is comparable in incidence with keratitis. It is to be noted, however, that such low glaucoma rates are atypical of the region, with 30.5:1,000 and 20.5:1,000 rates recorded for Abai district and Semipalatinsk Province, respectively. They are similar, however, when compared with the 4.8:1,000 rate for the former Soviet Union, and with the rate of 4.6:1,000 established for the control Kokpekty region.

The prevalence of conjuctivitis, the second most frequent eye disease, was 9.9% in Kainar and 5.7% in Sarzhal.

Special attention of the mission's ophthalmatologist, N.S. Kenzhebaiev, was directed by the local eye specialists to the recently increasing occurrence of retinal vessel degeneration. A survey program that was undertaken involving 284 inhabitants of the subject area led to the identification of 123 cases. The relative frequency among adolescents (8 to 15 years of age) surpassed even that for the adults, reaching as high as 30%.

Unrelated to age, but also very high, was the incidence of refraction anomaly, with 73 cases detected on the same program out of the total of 285 surveyed.

3.16 Otorhinolaryngological Diseases

The otolaryngological disease rate for Kainar is twice that of Kokpekty; the reason is that Kainarians are more afflicted by chronic inflammations, such as otitis, pharyngitis, and laryngitis.

Dental service at Sarzhal, and especially Kainar, is poor; as a consequence, every fourth inhabitant has cavities, in many cases complicated with pulpitis. Periodontal disease also seems to be widespread.

3.17 The Diseases of Children

Doctors Satpanbaeva, Koshpekova, and Kamasheva, the three pediatricians on the mission, examined a total of 444 children. The Kainar group was made up of 136 girls and 112 boys, and the group in Sarzhal consisted of 104 girls and 92 boys. More detailed examinations were carried out, and requisite treatment prescribed, by specialist doctors to whom some of the chidren were referred.

The primary examination in Kokpekty was assigned to a pediatrician (Dr. Sat-

pambetova) and a nurse. The specialist services of urologists, endocrinologists, and so forth were sought as required. Based on the results of primary examination, some children were also given endoscopic and ultrasound check-ups. Hematological and biochemical investigations were carried out according to predetermined criteria. X-ray tests were not performed as part of the examination. The survey contingent totaling 344 children (up to age 16) was represented by 153 boys and 191 girls. The age groups of 1-6 and 6-15 years of age consisted of 142 and 202 children, respectively.

The report of the examination team supports the previous conclusions about an alarmingly high level of childhood morbidity in the subject villages. The number of clinically healthy children in Sarzhal was only 8 out of 196, while the number of illnesses detected totaled 455, an average of 2.5 per child. Similarly, only 30 out of 248 children examined in Kainar proved healthy; on the basis of 2,252 illnesses per 1,000 population, the morbidity index was therefore 2.3 illnesses per child (Table 52).

Table 52. Incidence and morbidity rates (per 1,000) of pediatric diseases in subject localities.

Disease Category	Kainar (N=248)	Sarzhal (N=196)
Kidneys and genitourinary tract	333	369
Psychoneuroses	419	529
Hematologic disorders	218	246
Infectious diseases and parasitoses	252	144
Diseases of the skin	131	139
Endocrinopathy	--	117
Cardiovascular diseases	151	---
Total	1504	1544

Only 40 (11.6%) of the children examined in Kokpekty qualified as being in generally good physical condition. The rest displayed various illnesses of varying degrees of severity. The overall ratio of the number of diseases (348) to the number of diseased children (304) was estimated to be 1.14, half the ratios in Kainar and Sarzhal. Comparable data per 1,000 children for the region were provided by Gordin [24] based on 1992 statistics:

Kurchatov City	108.1
Semipalatinsk City	128.1
Semipalatinsk Province	145.0

Every third child in both Kainar and Sarzhal was found to have a urological disorder. Urocalculous diathesis was diagnosed in nearly every fifth child of preschool age.

Diseases of the gastrointestinal tract appear to be frequent: chronic gastritis, gastroduodenitis, various biliary tract disorders, and chronic colitis were diagnosed in 48 children of Kainar (19.3%) and 40 children of Sarzhal (20.4%), respectively. The examination involved only school-aged children, so the actual incidence may be higher, comparable to the 24.3:1,000 and 34.3:1,000 reported by Gordin [24] for Semipalatinsk Province and Kurchatov City.

Dermatopathic examinations yielded incidence rates of 19.3% and 27.6% for Kainar and Sarzhal, respectively. Allergenic dermatoses and infectious or parasitic diseases of the skin are more typical of Sarzhalians, while congenital and dystrophic varieties prevail in Kainar.

Childhood developmental anomalies identified by the mission are listed in Table 53. Technically, this kind of examination presented the doctors with problems. The culture, especially in rural areas, would not allow parents to let strangers see the children with congenital deformities, not to mention bringing their attention to such disabilities. The data, therefore, should be analyzed with this cultural factor in mind. Not included in the table are the data on congenital and dystrophic diseases of the skin or congenital psychological defects, as these data are featured in these specific sections.

Table 53. Number of cases of childhood developmental anomalies in the subject locations.

Anomaly	Kainar	Sarzhal
Valgus of the foot	3	2
Abdominal hernia	4	3
Short frenum of the tongue	2	1
Upper iris detachment	--	1
Cryptorchidism	1	1
Phimosis	2	1
Hypostrature*	--	1
Scoliosis	4	4
Total	16	14

* Hypostrature is the early overgrowth of cranial bone joints, leading to craniostenosis and microcephalopathy.

The congenital childhood deformity rate is 64.5:1,000 in Kainar; a rate of 71.4:1,000 has been established for Kainar. The former figure corresponds exactly with that for the 1992 Semipalatinsk Province rate, representing an increase of 10.4 points over the same year's rate reported for Semipalatinsk City (54.1:1000).

Infectious and parasitic diseases, such as brucellosis, enterobiasis and lambliasis, appear to affect the children of Kainar and Sarzhal at the respective frequencies of 19.8% and 14.3%. In each village, two cases of active tuberculosis were diagnosed.

Due to a lack of proper care, tonsillitis (chronic and subacute) seems to be almost endemic for the younger generation of both Kainar and Sarzhal. There were 68 and 72 cases, respectively. Caries, including the multiple variety, was

found to be frequent, and in many cases complicated by otitis and pharyngitis as well as by cardiovascular system malfunction.

Cardiopathic disorders were detected in eight children of Kainar and 16 children of Sarzhal. An additional 16 and 17 children in each village, respectively, had hypertensive syndrome and vegetovascular dystonia.

Twelve youths of Kainar were affected with hemorrhagic syndrome complicated by petechiae and nasal hemorrhages; the corresponding number of cases for Sarzhal was nine. In Kainar and Sarzhal there were 58 and 71 children, respectively, suffering from anemia.

Endocrinopathy, represented primarily by thyroiditis and thyroid gland hyperplasia, occurring mostly in the 1st and 2nd stages of development, was affecting 36 and 28 children of Kainar and Sarzhal, respectively.

Fourteen and sixteen children of Kainar and Sarzhal, respectively, were found to be affected with rickets. Additionally, in the same groups, there were four and seven cases of hypotrophy. The mothers of all these children suffered from anemia.

The most frequent eye disease occurring in Sarzhal was conjunctivitis (8 cases out of 57 children examined by the ophthalmologist). There were also 13 cases of strabismus and 5 of myopia. The retinal blood vessels showed deviation from the norm in 15 cases, and anomalous refraction was additionally detected in 12 children. Optic nerve anomaly in the form of papilledema was discovered in four cases.

Psychoneurological diseases were diagnosed in 40 and 42 children of Kainar and Sarzhal, respectively. The relevant data for Semipalatinsk Province [25] indicate a rate of 457.8:1,000, which is 1.5 times the national rate. More details on children's health in the three villages are included in the Appendix.

3.18 Hematological Studies

Erythrocytes

The erythrocyte concentration was measured in 167 native inhabitants of Sarzhal and 64 people who moved to the village after 1965 and was found to be roughly equal for both groups. However, every third person of the former group was diagnosed for anemia, with 3.2 to 3.8 x 10^{12} cells per liter of blood, on the average. All of the cases were women of middle age, and in many of them the hemoglobin rate was as low as 6.8 mmol/l.

Microscopic laboratory tests revealed a high incidence of anisocytosis, poikilocytosis-, and the presence of microerythrocytes. Hypochromic erythrocytes having basophilic granules, Cabot's ring bodies and Howell-Jolly bodies were discovered in 40% of the cases examined and were generally, but not always, associated with the lower (3.2 x 10^{12}) erythrocyte count.

In Kokpekty, the average erythrocyte count in men (N = 120) was 4.64 ± 0.31 x 10^{12}/l, which was in very close agreement with controls. The peripheral blood count norm was evaluated by Gusev and Rakhimgalieva to be 4.6 ± 0.35 x 10^{12}/l. The corresponding value for women was 3.81 ± 0.29 x 10^{12}/l, which is somewhat lower than the blood count norm in controls, 4.2 ± 0.33 x 10^{12}/l. The

erythrocyte count, taken in 64 children, was 4.1 ± 0.15 x 10^{12}/l. Erythrocytes with basophilic granules (hypochromia) and Cabot cells containing erythrocytes were mainly noted in women with relatively low erythrocyte counts.

Hemoglobin Level

Based on the mean values obtained, adult males appeared to have sufficiently high hemoglobin levels: the typical level for 20- to 30-year-old men was 8.2 mmol/l (Table 54). At the same time, 11% of the examined men were stratigraphically determined to be slightly anemic, with rates lying between 5.6 and 6.8 mmol/l.

Table 54. Hemoglobin levels in male and female individuals in Sarzhal and Kokpekty (number of cases).

Hemoglobin level (mmol/l)	Sarzhal (age 20-30)	Sarzhal (31-40)	Sarzhal (>40)	Sarzhal Total	Kokpekty Total
Males				**(N=165)**	**(N=120)**
>8.1	19	20	45	84	73
6.8-8.1	15	18	30	63	42
5.6-6.8	--	12	6	18	5
<5.6	--	--	--	--	--
Mean:	8.22 ± 0.23	7.87 ± 0.21	8.05 ± 0.16		
Females				**(N=220)**	**(N=100)**
>8.1	--	5	15	20	8
7.4-8.1	4	9	21	34	48
6.8-7.4	10	29	41	80	21
5.6-6.8	8	24	28	60	18
<5.6	4	11	13	28	5
Mean:	6.42 ± 0.24	6.35 ± 0.22	7.09 ± 0.16		

By contrast, the mean values obtained for women of all age groups were definitely much lower than the norm: a level of 7.4 mmol/l was found in only 54 cases out of the total number of 220. Moreover, acute anemia (< 5.6 mmol/l) was ascertained for 280 women, mostly in a group of multiparous women under 40. Both men and women were found to be equally inclined to slight anemia after 40. Hyperacute anemia (< 4.4 mmol/l), which represents a direct menace to life, was diagnosed in 9.4% of the women between 30 and 40 years of age.

For Kokpektians, the hemoglobin ranges between 133-158 g/l (8.2-9.8 x 10^{12} mmol/l) in males and 115-139 g/l (6.2-8.6 x 10^{12} mmol/l) in females. Thus, the lower level of Hgb for male and female inhabitants of Kokpekty was taken to be less than 130 and 120 g/l (8.0 and 7.4 x 10^{12} mmol/l), respectively.

Thus, the hemoglobin rate in 39.2% of Kokpekty males is below the regional norm, with acute anemia (6.8-5.6 x 10^{12} mmol/l) recorded for 4.3% of the men

examined. The hemoglobin content is similarly below the norm in half the Kokpekty women; the 7.4-5.6 x 10^{12} mmol/l bracket data reveal a relatively higher level of pernicious anemia, with five cases warranting immediate medical treatment. The relationship of age to hemoglobin was not addressed in this survey.

Leukocytes

The leukocyte concentration was measured in 286 Sarzhalians (112 males and 174 females). Depending on the age, the mean varied from 5.15 to 6.59 x 10^9 cells per liter of blood with men, and from 5.13 to 5.69 x 10^9 with women (Table 55). It follows that the adult population in Sarzhal is not affected by leukopenia. It is noted, however, that in about a fifth of the people examined, the number was around 4.5 x 10^9 cells/l.

Table 55. Leukocyte counts in Sarzhal by gender and age and in Kokpekty by age only (number of cases).

	Age groups			
Leukocyte count (cells x 10^9/l)	**20-30**	**31-40**	**>40**	**Total**
Sarzhal				
Males				
<4.0	--	3	--	3
4.0-4.5	8	3	10	21
4.5-5.0	--	6	6	12
5.0-6.0	10	7	15	32
6.0-7.0	4	3	7	14
>7.0	2	12	16	30
Total	24	34	54	112
Mean	5.77 ± 0.51	6.30 ± 0.48	6.05 ± 0.46	
Females				
<4.0	--	6	13	19
4.0-4.5	1	4	8	13
4.5-5.0	2	13	20	35
5.0-6.0	10	19	17	46
6.0-7.0	2	6	13	21
>7.0	4	2	12	18
Total	19	50	83	152
Mean	5.13 ± 0.44	5.55 ± 0.21	5.60 ± 0.16	
Kokpekty				
<4	1	4	7	12
4.1-5.0	12	21	28	61
5.1-6.9	22	41	49	112
>7.0	2	3	3	8
Total	37	69	87	193

The results of the present determinations are in general agreement with the data by Zhangalieva [26], who examined 199 native inhabitants of Sarzhal and found the mean number to be 5.25 x 10^9 cells/l. The mean leukocyte number established for 64 individuals who had moved to Sarzhal after 1966 was 5.88 x 10^9/l, representing a statistically insignificant difference. At the same time, it was noted that in 20.7% of the native cohort the mean number ranged from 3.2 to 3.8 x 10^9/l.

Leukocyte counts for peripheral blood were made in 196 Kokpektians, of which 79 were women. No immediate relationship between gender and leukocyte count was discovered, so further analysis along this line was abandoned. Rakhimgalieva [27] provides several data concerning leukocyte counts. She noted that one-fifth of the total of 950 persons examined had a peripheral blood leukocyte count of less than 4.1 x 10^9/l. On the other hand, a similar percentage of these persons had higher than normal leukocyte counts.

Erythrocyte Sedimentation Rate

The average ESR rates for healthy inhabitants of Semipalatinsk Province are 5.5 + 3.0 and 8.8 + 4.5 mm/hr for males and females, respectively; the ranges are 1.0-8.0 and 4.1-12.6 mm/h. ESR figures 20 mm/h or higher were considered by these workers to be abnormal and an indicator of the presence of organic cardiac pathology. We see an abnormal ESR as a generic indicator of dysfunction of the total organism.

Subjects were grouped into three age categories (Table 56). In Sarzhal, deviant rates were observed in each age group, but they occurred in the ratio of 1:1.7 between the young (20-30) and middle-aged people (>40). It is to be noted that the greatest deviations (over 10 mm/h) and most evident abnormalities (over 20 mm/h) were displayed by people in the oldest age group; many of them were most likely fallout victims in their early childhood.

Table 56. ESR data for Sarzhal and Kokpekty by gender and age.

Sex	ESR (mm/h)	20-30 years	31-40 years	>40 years
Sarzhal				
Males (N=110)	<10	20	24	34
	10-20	2	8	18
	>20	--	2	2
	% ESR >10	9.1	29.4	31.1
Females (N=168)	<10	10	18	38
	10-20	12	18	46
	% ESR >10	54.5	57.1	63.0
Both sexes	% ESR >10	31.8	44.7	54.4

Table 56. Continued

Sex	ESR (mm/h)	20-30 years	31-40 years	>40 years
Kokpekty				
Males (N=120)	1-10	21	28	47
	11-20	4	8	5
	>20	1	2	4
	% ESR >10	19.2	26.3	16.1
Females (N=90)	1-10	10	27	28
	11-20	3	4	13
	>20	--	3	2
	% ESR >10	23.1	20.1	34.9

The ESR parameter was found to be more affected in women than in men: within the 20- to 30-year-old group, the male-female ratio was 1:6. In the females examined, 45.3% had ESRs greater than ten mm/hr, and 15.5% had greater than 20 mm/hr; the percentages for males were 23.1% and 3.6%, respectively. The ESR divergences are most probably caused by the morbidity of the majority of Sarzhal's population.

In Kainar, abnormal ESRs, particularly those above 20 mm/h, occur more often in women than in men. The male age group with the highest rates (11 mm/hr and above) is the 31-40 age bracket, while in the case of women the highest rates are in those women over 41. Among the women with ESR > 20 mm/h, three were found to be clinically ill, whereas no clear pathology could be associated with high ESR in the rest of the cases.

There is little background information with which to compare the present ESR results. While Sasaki et al. [28] attribute the ESR drop in the nuclear attack victims to the effects of irradiation, no ESR divergences were discovered by the field examinations during 196274, which involved approximately 10,000 inhabitants of Abai, Zhana-Semey, and Beskaragai districts. The ESR tests, unfortunately, were not included in the program of the 1956-1959 missions organized by the Kazakh Academy of Sciences and the Moscow Institute of Biophysics.

This portion of the report does not include the results of the laboratory investigations we conducted in the areas of cytogenetics, cell and humoral immunology, or the study of the physical state and functioning of erythrocytes.

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Conclusions

The findings of an extensive medical and dosimetric survey conducted at Kainar, Sarzhal, and Kokpekty of Semipalatinsk Province are reported. The project was implemented in 1994-1995 by a special-purpose team fielded by the Semipalatinsk School of Medicine and the Institute of Medical Radiology and Ecology.

Kainar and Sarzhal and Kainar have been under observation since 1957 as population points at the periphery of the Semipalatinsk Nuclear Test Site (STS) with a history of multiple exposures to fallout. The control village, Kokpekty, lies at a distance of some 350-450 km from the STS. Thanks to this, and its position off the prevailing wind patterns, this village happened to remain largely unaffected by fallout. The external dose received by humans was within 7-10 rad, consigning the area to the minimal radiation risk group [1]. External radioactivity at Kokpekty is largely due to the global background, even though the measurements revealed the presence of photopeaks characteristic of trans-uranium elements, testifying to the presence of fallout attributable to STS activities. This fallout, however, did not contribute to internal or external doses to an extent detectable by medical examination.

Kainar, Sarzhal and Tailan (a small village area near the test site also heavily affected by fallout) all have a history of multiple test-induced contaminations. In all three areas, anthropogenic Cs-137 and Sr-90 nuclides have been observed. The heaviest concentrations of Sr-90 and Cs-137 in the ground were found at Kainar and Sarzhal, both on the surface and at depths of 20-25 cm. Layer-by-layer measurements pointed to a slower migration rate of Cs-137 compared with Sr-90. The Cs-137/Sr-90 ratio for the topsoil is 3.5, 6.94, and 1.65 for Kainar, Sarzhal, and Kokpekty, respectively. These ratios are in agreement with those for global fallout, obtained from the Meteorological Service of the Republic of Kazakhstan. The presence of Cs-137 at depths greater than five cm is evidence for its origin from nearby STS nuclear explosions. Subsoil concentrations of these nuclides have been found to deviate considerably from global fallout measures and to approach one in Sarzhal and Tailan, while measuring 3.5 in Kainar.

According to spectrographic analysis of photopeaks of the soil samples, all of the subject areas reveal the presence of underground Am-241, Eu-152, Eu-154, and other rare earth elements. Deep subsoil at Sarzhal and Kainar appears to include unidentified sources of pure α-radiation with intensities of three to five times over the background. A study of the potential role of this radiation in adversely affecting the public health in these areas should be given high priority.

It should be noted that at the present time the external radioactivity levels at the three areas studied are within current standards.

Plant pollution is brought about by root absorption and dust precipitations. The levels of long-lived radionuclides in the pasture grass and hay are six to eight times as high at Kainar and Sarzhal as they are at Kokpekty. The accumulation of Sr-90 in plants at Kokpekty is 3-10% of its soil surface content, while it is 20-30% at Kainar and Sarzhal. The soil-to-plant transfer ratio is 22.8% for Sr-90 and 6.8% for Cs-137. Understanding of this disparity requires further study.

The annual dose absorbed internally from ingestion of water and foodstuffs contaminated by fallout, estimated from the environmental Cs-137 concentrations, is 38.2 microGy at Kainar, which is five times the value of the dose established for the other villages (Sarzhal = 8.776 microGray, Tailan = 8.132 microGray, and Kokpekty = 8.573 microGray). The equivalent ingested dose (neglecting the bone tissue damage factor) due to food is 980.6 microSv at Sarzhal and 604.3 microSv at Kokpekty; the total dose ratio (of internal irradiation) between Sarzhal and Kokpekty is therefore 1.6. The prevalent ingested nuclide has been determined to be Sr-90, with overall percentages of 92 and 94 for Sarzhal and Kokpekty, respectively. The impact of Sr-90 was assessed without regard to national dietary customs.

The dosimetry results obtained in the present investigation and the conclusions they offer can serve as a basis for further studies. A more accurate description of the radiological situation in the subject localities is only possible if the scope of the exploration is made significantly broader. Priorities that hold much promise include specific dietary studies to be conducted in each of the subject areas and mapping out the spatial distribution of the fallout through extensive soil sampling.

Morbidity levels at Kainar and Sarzhal are more than twice as high as those at Kokpekty. For certain nosological groups of diseases and specific ailments, the ratio is still higher. Kokpektians are 1.5-2.0 times less susceptible to hypertension, myocardiodystrophy and diseases resulting from coronary vessel damage. The incidence of neurocirculatory dystonia is 1.6 to 2.0 times lower at Kokpekty than at Sarzhal or Kainar. Over the last 40 years, significant changes have taken place in the state of blood pressure at Kainar and Sarzhal: the formerly widespread hypotension, affecting approximately 50% of the total adult population, has been replaced with hypertension, which now is common to all age groups 30 years of age and older. In addition, the hypertension rate is 1.6-1.7 times higher than in Kokpekty.

Endocrinopathy has been diagnosed in every fourth inhabitant of the two study areas. There has been a notable rise in goiter incidence at Kainar and Sarzhal over the last twenty years.

Collagen-vascular diseases, with a clinical course involving autoimmune manifestations, are also widespread throughout the study areas. The incidence is 2.0 and 1.3 times lower at Kokpekty than at Kainar and Sarzhal, respectively.

Uronephrological conditions were detected in every second Kainarian and every third Sarzhalian, with half of the cases associated with nephropathy.

Dermopathy occurs 3.5 and 2.0 times as frequently at Kainar and Sarzhal, respectively, as at Kokpekty, while syndromes resulting from congenial metabolic defects and dystrophic diseases with autoimmune manifestations damage are 6 times higher than at Kokpekty.

The incidence of mental diseases is 3.1 to 3.7 times higher at Kainar and Sarzhal than at Kokpekty.

The women of Kainar and Sarzhal were noted for premature (40-55 years of age) involution of the external genitalia, primarily in the form of senile colpitis, which is virtually nonexistent at Kokpekty. The onset of the menstrual cycle takes place at an older age at Sarzhal and may sometimes be delayed to as late

as 24 years of age. Premature menopause with age of onset prior to 42 occurs twice as frequently at Kainar and Sarzhal than at Kokpekty.

The number of children examined was sufficient to draw significant conclusions regarding their health status. The morbidity rates of the children in general reflect those of the adults, being 2.2-2.4 higher at Kainar and Sarzhal than at Kokpekty. For certain nosological groups of diseases and specific ailments the difference is even greater. The rates for mental, hematological, and skin diseases are four to five times as high for children compared to adults. Every fourth child is anemic.

Since high morbidity rates in mothers gives rise to higher premature births and delayed development, children are at greater risk for hard to cure hypotrophy, rickets and, at a later stage, chronic tonsillitis. As a result, an increased incidence of nephrosonephritis and pyelonephritis was observed.

Dystrophic and congenital skin conditions (ichthyosis, psoriasis, dyschromia, etc.) are common for Kainar and Sarzhal, while at Kokpekty they are relatively rare. The clinical courses of dermatoses of various etiologies displays characteristics of allergies, and occur six times as frequently in Kainar and Sarzhal as Kokpekty. The overall adverse effect on the development of children is reflected in the fact that young Kainarians were some three to six cm shorter than children the same age from the cities of Semipalatinsk and Almaty [2].

A straightforward interpretation of peripheral blood data is sometimes difficult. The morbidity rates for somatic diseases in general and infectious diseases saw a sharp rise in Semipalatinsk Province, just as they did throughout Kazakhstan, during the 1930s after the centuries-old way of life was overthrown. In an attempt to eliminate bias, the values were averaged, and the resultant indices, which differ somewhat from official statistics, were used as reference in our studies.

The peripheral blood indicators vary greatly between Kainar and Sarzhal on the one hand, and Kokpekty, on the other. ESR deviations of over ten mm/h are present in one-third of men and in 60.7% of women in Kainar and Sarzhal; these deviations are 1.5 and 2.0 times greater than at Kokpekty. Moreover, abnormal ESR is twice as frequent over 40 years of age. Almost a half of female Sarzhalians are anemic with a hemoglobin rate below 6.8 mmol/L. The white blood profile is also irregular, with higher incidences of both leukopenia and leukocytosis.

The life expectancy, an integral health status indicator, is greatly aberrant, measuring 56.8 years at Kainar and 58.3 years at Sarzhal, while Kokpektians live 5 years longer, and the national average is ten years greater (67.6 years).

It is felt that our findings present a fairly accurate picture of the public health status in the study areas. It is possible that several numbers may differ significantly from official statistical data, since the observed subjects did not comnprise more than a third of the total population.

The climatic conditions and life styles in all study areas are similar. The areas are exclusively rural cattle-breeding areas, with limited or no use of pesticides or fertilizers. It is therefore inferred that high morbidity rates should be attributed to ionizing radiation resulting from nuclear test fallout in sublethal doses, which occurred several times during the period of above-ground testing. The last above-ground test was more than 30 years ago (at time of writing of this

paper), and less than a half of the directly exposed persons are now living. The people born after 1965 account for 60-70% of the study cohort. There is therefore a need to determine what causes high morbidity rates in the posterity of irradiated individuals. This objective can only be met by a specially designed study project.

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Appendix A

Table A1. Levels of radiation contamination from nuclear testing around the STS during 1949-62.

Locale	Distance from epicenter (km)	Dose rate during measure-ment (R/hr)	Time between explosion and measurement (hours)	Duration of fallout (hours)	Total γ dose on the surface (R)	Total γ dose on the popula-tion (R)
1949 Test: 20 kt above ground						
Beskaragai Region						
Budeno	98		165	3.6	256	180
Dolon	118	0.12	173	3.4	200,224*	160,134*
Cheriomushky	76		173	3.0	167	110,100*
Mostyk	90		173	3.4	157	110,90*
Kanonerka	129				175	114,112*
Novo-Nikolaevka	162				34	22
Undyrzh	147				19	15
Ramadan	120				29	16
B-Vladimir	120				36	21
Grachy	79				14	7
Topolena	75				14	9
Belokamenka	122	0.000036	173	3.4	6	5
Baidaulet	62				21	16
Zhana-Semei Region						
Glukhovka	138				6	7,4*
Turkai	136				6	7,4*
Sotzialisti-cheskoy	129				6	7,4*
Borodulikha Region						
Borodulikha	147				14	12,11*
Dmitriyevka	141				16	13,12*
Kamyshenky	153				11	10,9*
Petropavlovka	161				10	8,7*
Mikhailenkova	161				7	7,5*
Novo-Shulybeksky Region						
Novo-Shulybek	212	0.00016	275	14.2	5.3	14,8*
Peschanka	216				6	7,5*
Proletarka	234				5.2	7,4*
Altai Territory						
Lokot	240	0.016	220	6	31	27,24*

Table A1. Continued

Locale	Distance from epicenter (km)	Dose rate during measure-ment (R/hr)	Time between explosion and measurement (hours)	Duration of fallout (hours)	Total γ dose on the surface (R)	Total γ dose on the popula-tion (R)
Kurya	340	0.0036	227	8.5	6.5	15,6*
Petropavlov-skoye	480	0.00029	255	12	1.6	0.6
Solton	653	0.00011	390	16.3	0.3	0.2
1951 Test						
Abai Region						
Kainar	150	0.27	10	10	49	39,37*
Kolkhoz Molotov	225	0.17	20	15	14	12,11*
Teskesken	410	0.004	20	27	0.3	0.2
Tespakan	460	0.002	20	31	0.12	0.1
Bestamap	211	0.11	20	15	13	12
Kzltas	231	0.14	26	20	9	9,7*
Ushbaik	236	0.11	29	23	7	9,5*
Akshatau	261	0.09	32	16	4	5,4*
1953 Test						
Abai Region						
Tailan	100	3	36.6	1.2	1000	
Sarzhal	110	1.19	25.7	1.3	250	100,42*
Karaul	200	0.18	84	2.4	150	100,37*
Kainar	150	0.9	35.6	1.3	150	100,43*
Konis	151	0.17	3	4.57	2	1.2
Kaskobulak	160	0.47	3	5.78	4.1	2.1
Kzitas	112	0.59	3	3.96	7.2	4.5
Zhana-Semei Region						
Znamenka	98	1.2	37.6	1.8	120	70
Terstambal	112				40	34,28*
Klementievo	126				14	12,10*
Sarapan	90	1.34	26	2.4	250	100,65*
Isa	89	1.34	26.5	1.6	250	100,98*
Charsk Region						
Charsk	203	1.7	90	2.4	10	9,7*
Suhuk-Bulak	179	0.6	95	2.6	9	9,7*
Bakarchik	215	0.3	95	1.7	10	9,7*
Angirzhal	300	0.04	25.6	3.5	0.6	5
Ayauz Region						
Ayauz	350	2.3	75	3.3	14	12,11*
Zhirma Region						

Table A1. Continued

Locale	Distance from epicenter (km)	Dose rate during measure-ment (R/hr)	Time between explosion and measurement (hours)	Duration of fallout (hours)	Total γ dose on the surface (R)	Total γ dose on the popula-tion (R)
Zhirma	262	0.8	112	3.1	7	6,4*
Chibartau	198	0.69	109	2.1	1.2	11,9*
1954 Test						
Kainar	117	0.22	3	3.54	2.7	1.3
Kzil-Adir	111	0.59	3	3.96	7.2	4.5
Kaska-Bulak	160	0.47	3	5.78	4.1	2.1
Sovkhoz Charsk	237	0.21	3	8.5	2.2	1.2
Sovkhoz Kaban-Chukur	327	0.1	3	11.7	1.0	1.0
Zharma	262	0.8	112	3.1	7	6,4*
Kapan-Bulak	270	0.6	118	1.2	9	9,6*
Sovkhoz Konaz	151	0.17	3	4.57	2	1.2
Sovkhoz Kaska-Bulak	160	0.6	3	6.5	6.5	3.2
1955 Test						
Kainar**	98	0.31	3	2.8	4.1	3.5
Kainar**	128	0.18	3	3.7	12.2	10.1
Znamenka	98	0.51	3.5	3.1	19.3	21,15*
Balterek	111	0.72	4.6	3.8	12.2	12,7*
Repinka	134	0.26	3.1	4.52	14	10
1956 Test						
Isa	89	0.0014	720	1.7	15	13,12*
Znamenka	98	0.0003	720	2.2	3	3,20*
Novo-Shulba	212				8	9,6*
Borodulikha	147				14	12,10*
Karasu	244	0.0002	720	4.1	1.7	
Borodino	263	0.0008	720	4.4	6.8	
Akimovka	335	0.0018	720	5.6	13	
Ust-Kamenogorsk	342	0.0016	720	5.7	10	18
Tarkhanka	364	0.0003	720	6.8	2.4	2.0
Borovka	345	0.0003	720	5.8	2.4	2.0
1957 Test						
Znamenka	98				35	37,30*
Kolkhoz 30 Years of Kazakhstan	90	0.05	8		8	2,1.5*

Table A1. Continued

Locale	Distance from epicenter (km)	Dose rate during measure-ment (R/hr)	Time between explosion and measurement (hours)	Duration of fallout (hours)	Total γ dose on the surface (R)	Total γ dose on the popula-tion (R)
1958 Test						
Sarzhal	110				21	38,19*
Charsk	203				6.3	11,8*
Oktyabrsk	189				5.4	8,5*
Zharma	262			1.2		7,5*
East Kazakhstan Province						
Borodino	263	0.0008	720	4.4	6.8	9,5*
Akimovka	335	0.0017	720	5.6	13	13,11*
Ust-Kamenogorsk	342	0.0016	720	5.7	10	18
Tarkhanka	364	0.00031	720	6.8	2.4	2
Borovka	345	0.0007	720	5.8	2.4	2
1960 Test						
Zhana-Semei Region						
Terstanbali	112				10	11,8*
Semenovka	114	0.22	3	3.6	2.4	7,3*
Topolka	75				1.5	2
1962 Test						
Semenovka	114				2	6,2*
Topolka	75				1.8	2.3
Dolon	118				15	14,11*
Semipalatinsk	137				0.9	5,3.2*
Kokpekty	290				0.3	0.2
Bolshaya Lukon	320				0.25	0.2
Aksaut	390				0.03	0.2
Urdzhar	570				0.003	0.3,0.15*
Makanchy	750				0.002	0.25, 0.11*

Source: Data were obtained from the USSR Ministry of Defense in response to a request from President N.A. Nazarbaev of Kazakhstan.

Note: Included in the table are the data for the tracts of land lying along the known tracks of radioactive clouds and for regions that feature accumulated outdoor γ radiation doses in excess of 1 R. The STS records provide no information on the delay time between tests and γ radiation measurements. Similarly, neither the cloud's arrival time, nor the wind velocity or cloud elevation are indicated. Also, information on radioactive precipitates fallout and radiation doses received at other population centers is lacking.

* Values separated by commas indicate the results of two or three different sources in the area, but by the same physicist-dosimetrist.

** During the year 1955, Kainar was subjected to two different tests. The readings for each test were taken at different places near Kainar, hence the discrepancy in distances from the hypocenter.

Table A2. Specific activity of various samples, Sarzhal (specific activity in Bq/kg or Bq/l).

Sample type	Sample date	K-40	Cs-137	Sr-90
Meat	4/30/81	53.76	0.01	0.037
		93.79	0.01	0.37
	2/19/82	147.6	0.01	0.148
	7/9/82	59.3	0.134	
	2/23/83	122.1	0.01	1.22
	12/15/83	99.24	0.01	0.037
	3/15/84	78.07	0.01	<0.02
	10/16/84	42.7	0.01	0.74
	3/20/86	76.6		0.3
	5/15/86	42.44		0.26
Milk	2/19/81	43.9	<0.3	<0.02
	4/28/81	53.35	0.3	0.37
	5/28/82	23.31		0.19
	3/12/83	30.3		0.41
	6/17/83	28.5		<0.02
	8/25/83	40.33		0.07
	12/26/83	22.2		0.26
	3/21/84	11.9		0.85
	8/6/84	11.8		0.67
	3/20/86	11.93		0.3
	5/12/86	31.13	11.3	0.1
	10/27/86	36.1		0.3
	7/9/92	70.4	0.4	

Table A3. Specific activity of various samples, Sarzhal (specific activity in Bq/kg or Bq/l).

Sample type	Sample Date	Depth (cm)	K-40	Cs-137	Ra-226	Ru-103	Ru-106	Ce-141	Sr-90	Zr-95
Soil	4/28/81		324.0	524.0	2.5				28.9	
	6/26/83		245.0	31.0	11.0				14.4	
	8/7/84		310.0	25.1	18.4				18.1	
	10/16/84		241.0	80.3	12.0					
	5/25/82	0-1	539.0	13.7	19.3				14.4	
	9/20/89	0-1	359.15	6.72	9.98					
				14.93	11.14					
	7/10/92	0-5	191.7	14.92						
	7/9/72		476.3	10.45						
		5-10	544.0							
		10-15	488.1							
Grass	2/17/81		56.0	5.95						

Table A3. Continued

Sample type	Sample Date	Depth (cm)	K-40	Cs-137	Ra-226	Ru-103	Ru-106	Ce-141	Sr-90	Zr-95
	4/28/81		22.95	1.39		1.65			1.2	1.85
	4/28/81		849.0	5.21	18.8			16.6	4.09	158.0
	4/29/81		24.6	2.8		9.9			10.6	19.8
	5/25/81		177.5							
	6/21/83		218.2			1.63			0.46	
	8/6/84		385.0	<2	140.0				1.5	
	9/24/87		343.0				26.0		12.0	
			498.0						7.4	
			184.0						10.4	
	6/14/88		847.0			8.1				
			818.0						3.72	
			839.5						3.42	
			546.1			4.2				
	8/31/88		1031.5				34.85			
			226.5				33.55		12.19	
Hay	5/12/87		486.3	105.8		14.7			11.16	
			243.0	100.0					13.2	
			335.0	163.6					16.6	
	12/15/87		337.02						22.6	
			9.5	33.0					1.12	
			187.0	41.0						
			408.0	52.0					4.67	
	12/8/88		130.7				40.5		23.67	
			79.8				48.35		29.04	

Table A4. Specific activity (Bq/kg or Bq/l) of various samples, Tailan.

Sample type	Depth (cm)	Sample Date	Cs-137	Ru-103	Ru-106	Co-60	I-131	I-132	Ce-144
Soil	0-1	9/9/68	673.4						
	0-5	6/1/70	7326			9,879			3,811
			8436			11,544			
	0-1	10/14/70	4329		10,360	1,554			
			4329		10,397	1,554			
			4329		9,916	1,554			
Vegetation (non-ashed)		4/28/74		884.3			3,485.4	1,690.9	
				88.8			312.7	101.4	
				4,366.0			13,690	8,214.0	

Table A4. Continued

Sample type	Depth (cm)	Sample Date	Cs-137	Ru-103	Ru-106	Co-60	I-131	I-132	Ce-144
				88.0			193.1	20.6	
				54.8			153.9	36.4	
				247.9			3,633.0	2,297.7	
				68.5			224.2	34.8	

Table A5. Specific activity (Bq/kg or Bq/l) of various samples, Kokpekty (control).

Sample type	Sample Date	Cs-137	K-40	Ru-103	Ru-106	Ce-144	Sr-90
Vegetation	7/3/81	1.45	252.7	3.85		21.75	
		0.89	359.9	2.73		28.25	
		1.44	320.8	3.92		18.67	
Meat	10/16/79	0.74	55.42		0.74		
			54.39				
	6/24/81		15.32				0.11
	6/30/81	0.63	54.3				0.15
			85.3				
			51.13				
	2/27/84		76.59				0.22
			55.76				
Bones	6/24/81				58.16	19.98	31.45
						15.54	17.02
						26.64	40.70
						37.00	39.96
							15.17
Milk	6/24/81	2.39	24.94			1.07	0.074
			44.36				0.15
			13.54				
Water	7.2.81		0.703			0.13	

Table A6. Specific activity of radionuclides in soil, plant, and foodstuffs samples, 1994, (Bq/kg or Bq/l).

Place	Material tested	Sr-90	Cs-137	Be-7	K-40	Ra-228	Th-228
Sarzhal	Soil 0-5cm	12.751 ±2.823	11.942 ±0.212	1.325 ±0.058	531.12 ±6.323	17.298 ±0.505	14.794 ±0.183
Sarzhal	Soil 7-12 cm	8.883 ±1.934	0.519 ±0.006	---	376.63 ±5.019	10.009 ±0.318	10.785 ±0.119
Sarzhal	Hay	3.683 ±0.661	0.816 ±0.311	249.712 ±15.73	216.51 ±16.123	2.689 ±0.836	2.737 ±0.463

Table A6. Continued

Place	Material tested	Sr-90	Cs-137	Be-7	K-40	Ra-228	Th-228
Sarzhal	Grass	1.417 ±0.174	0.459 ±0.106	196.732 ±5.351	367.13 ±10.321	1.086 ±0.163	0.691 ±0.114
Sarzhal	Meat	0.672 ±0.154	0.185 ±0.012	0.919 ±0.131	74.93 ±4.624	---	0.048 ±0.019
Sarzhal	Milk	0.514 ±0.123	0.049 ±0.027	---	24.45 ±1.513	---	---
Sarzhal	Water	0.583 ±0.131	0.039 ±0.005	---	---	---	---
Sarzhal	Bones	12.082 ±2.174	---	4.895 ±1.45	42.63 ±8.172	6.391 ±0.672	4.144 ±0.343
Tailan	Soil 0-5 cm	9.324 ±2.052	11.058 ±0.258	---	324.41 ±4.334	11.891 ±0.179	10.958 ±0.042
Tailan	Grass	1.068 ±0.164	0.518 ±0.051	15.902 ±1.153	197.63 ±12.86	0.767 ±0.396	0.628 ±0.107
Kainar	Soil 0-5 cm	14.861 ±3.260	51.957 ±0.179	---	752.43 ±6.683	25.189 ±0.179	22.333 ±0.113
Kainar	Soil 20-25cm	12.320 ±2.741	1.432 ±0.027	---	599.62 ±5.313	21.719 ±0.111	23.646 ±0.094
Kainar	Hay	3.701 ±0.640	3.937 ±0.024	74.723 ±4.681	66.22 ±5.364	3.277 ±0.494	2.065 ±0.098
Kainar	Grass	1.091 ±0.034	1.095 ±0.143	49.914 ±3.221	434.74 ±26.83	2.024 ±0.308	2.123 ±0.157
Kainar	Milk	---	0.044 ±0.004	---	31.04 ±1.932	---	---
Kainar	Water	---	0.025 ±0.002	---	1.37 ±0.161	0.083 ±0.013	0.018 ±0.011

Table A7. Specific activity of soil samples from right bank of Kokpekty, 1994* (Bq/kg) at various depths.

Nuclide	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm
Sr-90	5.234 ± 1.011	2.824 ± 0.484	1.435 ± 0.311	1.056 ± 0.233	0.372 ± 0.081
Cs-137	8.583 ± 0.039	1.966 ± 0.005	0.699 ± 0.026	0.495 ± 0.065	0.381 ± 0.006
K-40	381.6 ± 3.421	488.7 ± 4.435	390.8 ± 3.509	390.6 ± 3.452	440.1 ± 3.935
Ac-228	19.794 ± 0.123	19.933 ± 0.161	17.532 ± 0.107	19.002 ± 0.108	28.379 ± 0.165
Pb-212	16.452 ± 0.068	23.619 ± 0.095	16.499 ± 0.068	15.891 ± 0.066	23.009 ± 0.089
Bi-212	15.253 ± 0.311	23.429 ± 0.333	16.953 ± 0.154	35.103 ± 0.355	24.491 ± 0.308

Table A7. Continued

Nuclide	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-25 cm
Tl-208	17.684 ± 0.095	19.238 ± 0.238	18.355 ± 0.096	25.851 ± 0.581	22.315 ± 0.122
Th-234	12.368 ± 0.205	14.476 ± 0.173	22.005 ± 0.389	25.651 ± 0.463	24.028 ± 0.912
Pa-234	2.647 ± 0.098	2.095 ± 0.098	3.055 ± 0.038	1.899 ± 0.026	2.801 ± 0.109
Ra-226	20.477 ± 0.561	19.241 ± 0.465	20.514 ± 0.516	16.292 ± 0.455	12.778 ± 0.383
Pb-214	11.684 ± 0.133	18.976 ± 0.133	11.847 ± 0.081	12.751 ± 0.056	10.833 ± 0.094
Bi-214	14.026 ± 0.066	19.381 ± 0.093	13.881 ± 0.062	15.073 ± 0.348	19.583 ± 0.099
U-235	1.263 ± 0.007	2.524 ± 0.076	1.484 ± 0.065	0.989 ± 0.005	1.713 ± 0.029

* The table cites the quality of examples from one point. Analogous examples for five layers are taken from six points. Calculations taken from average values.

Table A8. Specific activity of samples from village of Kokpekty, 1994 (Bq/kg or Bq/l).

Nuclide	Vegetation from right bank	Milk*	Meat**	Bones***	Drinking water samples 1&2 (right bank)****	Drinking water samples 3-6 (left bank)****
Sr-90	0.404 ± 0.023	0.072 ± 0.025	0.015 ± 0.007	1.783 ± 0.107	0.312 ± 0.071	0.601 ± 0.181
Cs-137	0.485 ± 0.115	0.052 ± 0.007	0.072 ± 0.019	1.386 ± 0.102	0.003 ± 0.001	0.006 ± 0.003
Be-7	106.200 ± 6.967	0.345 ± 0.101	58.933 ± 3.601	0.345 ± 0.141		
K-40	194.800 ± 13.525	25.691 ± 1.625	0.791 ± 0.161	22.148 ± 6.072		
Ra-228	7.008 ± 0.955	0.350 ± 0.036	0.796 ± 0.012	4.201 ± 0.536	0.017 ± 0.013	0.019 ± 0.017
Th-228	0.572 ± 0.098	0.121 ± 0.015	0.808 ± 0.064	0.808 ± 0.156	0.011 ± 0.005	0.009 ± 0.003
Bi-212	6.541 ± 0.791	1.103 ± 0.124	0.787 ± 0.049	--	0.016 ± 0.010	0.015 ± 0.011
Tl-208	3.279 ± 0.217	0.135 ± 0.019	0.133 ± 0.087	2.818 ± 0.135		
U-238	1.275 ± 0.955	0.234 ± 0.123	0.078 ± 0.016	--		
Pa-234	0.751 ± 0.342					

Table A8. Continued

Nuclide	Vegetation from right bank	Milk*	Meat**	Bones***	Drinking water samples 1&2 (right bank)****	Drinking water samples 3-6 (left bank)****
Ra-226	1.029 ± 0.172	0.244 ± 0.041	0.376 ± 0.121	1.476 ± 0.240	0.031 ± 0.021	0.007 ± 0.006
Pb-214	0.762 ± 0.049	0.444 ± 0.071	0.172 ± 0.031	1.564 ± 0.032	--	0.002 ± 0.002
Bi-214	0.978 ± 0.409	0.219 ± 0.019	0.168 ± 0.045	1.381 ± 0.260		
U-235	0.073 ± 0.005	0.013 ± 0.005	0.089 ± 0.005	0.088 ± 0.005	0.002 ± 0.001	0.001 ± 0.001
Th-227	2.254 ± 0.1970		0.043 ± 0.004	2.331 ± 0.134		

* Information used for dose computation taken from results of six measurements of milk: average Cs-137 is 0.069 ± 0.004 Bq/l; average Sr-90 is 0.059 ± 0.008 Bq/l.

** Information used for dose computation taken from results of six measurements of meat: average Cs-137 is 0.090 ± 0.007 Bq/kg; average Sr-90 is 0.029 ± 0.005 Bq/kg.

*** Information used for dose computation taken from results of six measurements of bones: average Cs-137 is 1.851 ± 0.149 Bq/kg; average Sr-90 is 4.823 ± 0.101 Bq/kg.

**** Information used for dose computation taken from results of six measurements of water: average Cs-137 is 0.005± 0.002 Bq/l; average Sr-90 is 0.457 ± 0.097 Bq/l.

Table A9. Otorhinolaryngologic and dental diseases in Kainar and Sarzhal in 1959 (number of cases).

Disease	Kainar (N=357)	Sarzhal (N=359)
Pharyngitis, laryngitis	64	43
Tonsillitis, chronic and subacute	21	22
Sinusitis	9	9
Leukoplakia	18	9
Bleeding nasal mucous membrane	14	16
Erosion and perforation of the nasal septum	16	10
Erosive/ulcerative stomatitis	12	8
Bleeding of the oral cavity, larynx, pharynx	6	47
Bleeding gums, purulent vesicles	244	143
Caries	98	59
Total:	502	366

Table A10. Time dependence for nervous system disease frequency in Kainar and Sarzhal from the time of STS fallout onset to 1994 (in percentage of cases).

Locality and Year	Number examined	Malfunction	Atherosclerosis, other vascular diseases	Other diseases
Kainar				
1957	258	76.7	7.1	3.1
1959	368	60.9	9.1	11.1
1994	408	42.4	16.2	13.5
Sarzhal				
1957	332	66.3	5.7	4.0
1959	365	59.8	4.4	5.1
1994	653	42.4	6.9	6.3

Table A11. Goiter (Stages I-IV) incidence in selected localities of Semipalatinsk Province in 1992, in percentages (cases/subjects).

Locality	Totals	Male	Female
Kainar	29.5 (203/693)	26.8 (68/254)	31.1 (135/439)
Sarzhal	38.2 (456/1195)	19.7 (113/573)	55.0 (343/622)
Kokpekty	30.3 (848/1548)	17.3 (121/469)	41.0 (348/848)

Source: Espenbetova [1]

Table A12. Time incidence of endemic goiter in Semipalatinsk Province.

Locality	Goiter rate in 1982	Goiter rate in 1992	Ratio of nodular to diffuse goiter
Abai district	13.2 ± 0.7	30.8 ± 0.8	1:4.5
Zhana-Semey district	13.3 ± 0.8	29.1 ± 0.6	1:4.5
Beskaragai district	7.3 ± 1.2	26.6 ± 0.6	1:4.4
Semipalatinsk city	21.6 ± 0.2	23.8 ± 0.4	1:6.8
Kokpekty district	29.2 ± 1.8	30.3 ± 1.0	1:10.2

Source: Espenbetova [1]

Table A13. Mental morbidity in different regions in Semipalatinsk Province in 1992.

Inhabited Locality	Morbidity (1/10,000)
Kokpekty	6.0
Ayaguz	8.0
Charsky	13.0
Zhana-Semey	15.3
Zharma	18.1
Abai	18.2
Beskaragai	30.8
Chubartau	36.3

Source: Raisov [2] (25, p. 178)

Table A14. (based on missing number from version of June 1999).

Table A15. Incidence of diseases of the kidney and urinary tract (excluding genital diseases) in the children of Sarzhal and Kainar, 1994 (number of cases).

Disease	Kainar (N = 248)	Sarzhal (N = 196)
Nephropathy (nephrosis, nephritis)	12	17
Pyelonephritis	24	20
Pyelocystitis	17	13
Urocalculous diathesis	19	16
Total	72 (29.1%)	69 (35.2%)

Table A16. Dermatopathic incidence in children in Kainar and Sarzhal, 1994 (number of cases).

Type of disease	Kainar	Sarzhal
Allergic dermatosis, including eczemas of various etiology and neurodermatitis	8	17
Infectious and parasitic diseases: pyodermas, impetigo, herpes, mange	12	25
Congenital and dystrophic dermatoses: dyschromia, ichthyosis, vitiligo, etiologically diverse exudative erythemas	18	12
Total	38	54

Table A17. Psychoneurological diseases of children in the subject areas, 1994 (number of cases).

Disease	Kainar	Sarzhal
Epilepsy	--	1
Down syndrome	--	1
Oligophrenia	1	2
Mental retardation	6	7
Somnambulism	--	1
Early childhood autism	--	1
Phobic neurosis	4	5
Encephalopathy (post-traumatic, antenatal)	6	5
Enuresis	23	19
Total	40	42

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